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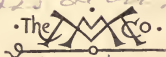
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LABORATORY PRACTICE FOR
BEGINNERS IN BOTANY

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LABORATORY PRACTICE

FOR

BEGINNERS IN BOTANY

BY

WILLIAM A. SETCHELL, PH.D.

PROFESSOR OF BOTANY IN THE UNIVERSITY OF CALIFORNIA



New York

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1900

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PREFACE

THE writer has been frequently asked to express to others his ideas on the subject of the teaching of botany in the schools. He has been led to consider the problem from a number of different points of view and to try a number of different methods in attempting a satisfactory solution. After experimenting with a number of classes of beginners both in the preparatory schools and in the university, he has arrived at the following conclusions : —

Botany in the preparatory schools should be taught —

1. As a science, to cultivate careful and accurate observation, together with the faculty of making from observations the proper inferences ; and
2. As a means of leading the mind of the student to interest itself in the phenomena of nature for its own further development and profit.

In order to make the study of botany more effective under the first head, it seems best to bring the student into immediate contact with the object itself, in the laboratory ; and not only that, but to avoid interposing apparatus, as far as possible, between the student and the object to be studied.

For this purpose, the writer has practically confined his attention to the larger plants.

Desiring also to cultivate, as far as possible, the ability to draw correct inferences from exact observations, the writer has deemed it best to consider the subject from a somewhat different point of view from that usually adopted, and has attempted to make the morphological study bear fruit in this direction. The great difficulty in most laboratory work is to make the students realize the significance of the morphological details. They may observe accurately and record their observations carefully, but what of that? The physiological significance is overlooked—even in many cases where experiments are used to illustrate physiological phenomena.

That the plant is a living thing, is a fact that must be borne *actively* in mind, both by teacher and by student. The plant must obtain the materials for its support, and to do this it must compete with other plants; it must protect itself against or seek the aid of animals; it must obtain the energy and materials to reproduce its kind, and endeavor to place its offspring where they may have a proper chance for development; and, destitute of a mind as it is, it exercises an ingenuity, so to speak, that is of no mean order. We must, then, think of the plant as a *living, working, struggling* being with a single object in life, viz. to reproduce its kind; and every variation in structure, be it great or little, is to be examined to determine, if possible, its use or history.

The writer has had the teachers particularly in mind in

arranging the order of study. The seed is taken up first, because it is not only readily obtained, readily studied, and its meaning clear, but it is also one of the most convenient starting-points for a study of the life-history. After a few studies to show how the plants start upon an independent existence, typical stems, roots, and leaves are considered, both as to their structure and as to their usefulness to the plant. Then follows the study of the modification of these organs, especially in plants which store away nourishment, which protect themselves from grazing animals, which climb up above their neighbors for light and air; of plants which are robbers or huntsmen, taking their food from other plants or by capturing animals; and finally, a glance at the different ways in which plants propagate their kind.

If both teacher and student can conceive of the plant in this way, an abundant harvest of interesting and instructive phenomena will be presented to view, and both will have come into far closer communion with nature than is possible in any other way.

In conclusion, the writer wishes to say that this sketch is intended for beginners, either in the higher grades of the primary schools, or in the secondary schools. It is not intended to hamper the teacher with too explicit directions, but to assist in directing attention to certain details and leave the teacher free to suggest farther work and thought upon each subject. In the second appendix, especial hints and suggestions are given to teachers, and references through which the writer hopes to convey to the teacher

the point of view which he himself takes in the particular exercise.

It remains to the writer to thank his colleagues in the University of California for their valuable aid in the preparation of this guide, and especially to Willis L. Jepson, who has made valuable suggestions at every point.

UNIVERSITY OF CALIFORNIA,
BERKELEY, CAL., Sept. 1, 1896.

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INTRODUCTION

BEFORE we begin to study plants in any way, we may, with profit, consider what sort of things are to be the objects to which our attention will be given. In taking a general survey of the objects we know in nature, and inquiring as to how we separate the plants from the rest, we consider, roughly at least, the following subjects :—

1. **Life.**—We readily separate, as far as most things are concerned, the members of the mineral kingdom from those which belong to the animal and vegetable kingdoms, distinguishing the two latter from the former by the fact that they are living. We need not undertake to investigate the nature of life, *i.e.* what life really is ; we may be content with considering it as a certain kind of force which manifests itself in certain ways through matter, and that upon the cessation of this force what we call death ensues.

2. **Plant and Animal Life.**—We distinguish, popularly, animal life from plant life in that the animal life is animated while the plant life is not. The ordinary animals exhibit various movements which they can control,—they eat, etc.,—and we do not question their living activities ; but the plants, with few exceptions, do not appeal to us as being

actively alive. We do not observe directly efforts that they are making to accomplish their life work. It is only by careful watching and observing that we can even begin to obtain any conception of their actual activities. On this account, it is especially necessary to keep in mind the fact that the plant is a living thing.

3. **Life-History.**—Each and every living thing has what is called a life-history; *i.e.* there is a certain beginning of its own separate life, which runs through certain stages, and there is finally an end to the life of that separate individual at least; *i.e.* it dies. This sequence of events from birth on to death is the life-history. With an ordinary flowering plant the life-history of the independent individual begins with the germinating seed, goes through the stages of seedling, mature plant, blossoming, fruiting, and ends with the mature seed. The parent dies, living on only in its offspring. Every plant, being a living thing, has a certain definite life-history, and this must be borne in mind throughout the work.

4. **Struggle for Existence.**—We ordinarily think that a plant simply grows and do not consider it a matter needing any forethought or trouble of any kind. But when we come to look at plants carefully, we find that forethought, or in other words, provision, exists by means of which seeds of different plants have a chance to get to favorable places for germination; that when there they may be able to hold their own to a certain degree, and not be crowded out by their neighbors; that certain ones can protect themselves against grazing animals; and that in every way each plant tries to obtain

a place to live in, to obtain its nourishment, to develop a healthy, vigorous body; all in order that it may produce a crop of good sound seeds. Every plant, we may say, is struggling against every other and against the animals, great and small, against certain unfavorable conditions of temperature, moisture, dryness, etc., and only the stronger and better equipped survive, while the weaker perish. This struggle, while not so evident, is fully as real as that going on between the different animals, and many peculiarities of plant structure are more or less readily explained upon this basis. What we must look for in our different laboratory studies, then, is to see how different plants have changed or modified very different parts to accomplish practically the same object.

5. Individuals, Species, and Genera.—Each separate plant is an individual. It is easy to distinguish the individual in almost all the higher plants, but occasionally the technical distinction may be somewhat difficult to establish. These technical difficulties need not, however, disturb us in our work at all.

We recognize that many individuals are of the same *kind* or *species*. They resemble one another so very closely, that there are no essential differences. We further recognize that there are *groups of kinds or species* more nearly resembling one another than they do other species; such as the different kinds of violet, the different kinds of roses, etc. These species we group under the head of *genus* (plural *genera*); e.g. we speak of the genus *violet* as including the

pansy, the English violet, and the various blue, white, and yellow violets. Genera are grouped into *orders* on account of resemblances, and orders under still larger divisions, etc. ; but the *genus*, *species*, and *individual* are all the beginner need trouble about, at least as far as the present work is concerned. When systematic work is taken up, the scheme of arrangement of the different subdivisions will gradually unfold itself.

LABORATORY PRACTICE

CHAPTER I

SEEDS

I. Take the ripened pod of a Bean Plant, and splitting it open, notice : —

1. That the seeds (Beans) are attached along one edge of each valve (or half) of the pod.
2. That each Bean is attached to the pod by a short stalk, the *funiculus*.
3. Make a sketch of a valve of the Bean pod with its enclosed beans, representing and labelling the parts.

II. Take a Bean which has been well soaked in water and examine, noticing : —

1. The general shape.
2. The color.
3. The scar or *hilum* on one side. (What caused the production of this scar?)
4. The heart-shaped purplish protuberance at one side of the hilum (more readily seen by the aid of a lens or magnifying glass). This is called a *strophiole*, and is present only in a few seeds.

5. The short ridge (use the lens) running from it toward one end of the seed. This ridge (called the *rhaphe*) runs from the hilum along upon the outside of the seed for a short distance, and then penetrating through the coverings of the seed, disappears into the interior. That portion of the *rhaphe* next to the hilum is covered, in the Bean, by the strophiole.
6. The small hole at the side of the hilum just opposite the strophiole. This is the *micropyle*, and is usually readily seen by the aid of the lens. If the surface of the seed is dried carefully, water may be made to ooze out of the micropyle, if the Bean is gently squeezed. This shows that the hole extends through the coats or coverings of the seed.
7. Sketch the Bean in such position as to show all of these parts, and label each distinctly.

III. With a scalpel or sharp penknife, make a cut along the edge of the Bean opposite the scar.

1. Remove the *seed-coats*. There are really two seed-coats, but they are so firmly united in the Bean as to be inseparable. The strophiole comes away with the seed-coats, for it is really a *rudimentary third coat*.
2. It will be noticed that the seed-coats are not attached to the contents (or kernel) of the seed except at one point, which is just under the place where the *rhaphe* penetrates the seed-coats. This point is called the *chalaza*. It is somewhat difficult to demonstrate, but if one takes a dry Bean (of the small white variety, commonly used for baking), and cuts out a crescent-shaped piece on the hilum side, taking care to include the free end of the *rhaphe*, one or both pieces of the

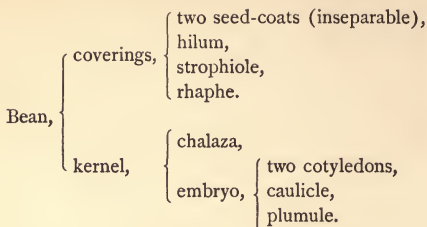
kernel will separate from the seed-coats, and the thread-like connection may be seen.

3. Examine and sketch the kernel of the seed, removed whole, noting : — *crisp*
4. The two thick halves, the *cotyledons* or *seed-leaves*, and
5. The single median structure, the *caulicle*. *from a callus*
6. Determine (in another Bean if necessary) whether the caulicle lies on the hilum side of the Bean or not, and whether its free end points toward the micropyle or not. *in a callus*

IV. Separate the cotyledons carefully along the side opposite to the caulicle, lay one of them over on its side and sketch the parts in this position, noting : —

1. The two cotyledons, their shape, thickness, and consistency.
2. The small projection (*auricle*) upon the inner side of each, beside the groove into which the caulicle fits.
3. The caulicle, its shape, consistency, and attachment to each cotyledon.
4. The small bud or *plumule*, showing two folded leaves on the outside, and lying upon the inner face of one of the cotyledons.
5. Notice carefully the veins of these two outer leaves of the plumule and also the character of the margins. How do they lie, relatively to one another?

V. It is to be noticed that the cotyledons, the caulicle, and the plumule are all joined together into one structure, which is called the *embryo*, or the part which is to grow into a new plant when the seed sprouts. We may represent the relations of the different parts we have learned about, as follows : —



VI. Take a Pea which has been well soaked in water, examine it as you did the Bean (II-V), and make sketches.

Are all the parts noticed in the Bean present in the Pea also?

Do you notice any differences in the shapes of the parts in the two seeds? If so, state them concisely.

VII. Take a Castor Bean¹ and notice : —

1. The general shape and coloration.
2. The resemblance to a beetle, such as a "June-Beetle" or a "Tick." (Could such a resemblance be of use to the Castor Bean?)
3. The prominence (or *caruncle*) at one end.
4. The depression in the caruncle, leading to the micropyle (sometimes difficult to find). The caruncle is an outgrowth similar to the strophiole of the Bean (see §§ II, 4, and III, 1), only it grows out around the micropyle instead of at the hilum.
5. The ridge (or streak) on one of the broader sides, the *rhaphe*.

¹ The pupil is warned not to taste the kernels of the Castor Beans, as they are *poisonous*.

6. The slight projection at the end of the rhaphe opposite to the caruncle (the *chalaza*).
7. The hilum is at the side of the caruncle toward the rhaphe, but is usually little prominent and hard to find.
8. Make a sketch showing these points.

VIII. Remove the dark-colored "shell," the *testa* or outer seed-coat, and notice : —

1. That the kernel is found to be enclosed in a thin, white, closely fitting *inner seed-coat*, the *tegmen*, which can be peeled off. *all shell*
2. After removing the tegmen, carefully split the kernel parallel to the broader surfaces. (This should be done very carefully so as not to injure the delicate parts within.) Notice the embryo adhering to one of the inner faces. By gently inserting the scalpel or pen-knife blade under the caulicle and loosening the cotyledons, the embryo may often be removed uninjured. Study and sketch : — *teg to cover*

1. The two thick pieces of oily *endosperm*, and the embryo consisting of *endo - wall*
2. A short thick caulicle and
3. Two thin, flat cotyledons, reticulated with prominent "veins" and closely applied to one another. Separate them after sketching and demonstrate that there are really two of them. *cent*
4. Is there any plumule present?

IX. Examine a seed of the Morning Glory which has been soaked a few hours in water. Answer the following questions : —

1. How many seed-coats can you find?
2. Is endosperm present?
3. If so, of what character is it?
4. What parts of the embryo are present?
5. How is the embryo packed away within the seed-coats?

X. Take a grain of Corn, softened and well swollen out by prolonged soaking, and notice : —

1. Its size.
2. Its shape.
3. At which end it was attached to the cob.
4. The differences between the two broader sides, viz. that on one side there is an indented tongue-shaped area wanting on the other. This tongue-shaped area indicates the position of the embryo.
5. At the top of the indented area there is either a small hole or a short fibre present, the remains or the point of attachment of a strand of "corn-silk."
6. Make sketches to show these points.

XI. Cut a grain of Corn into two pieces, in a median longitudinal plane, perpendicular to the broader surfaces. On one of the cut surfaces, notice : —

1. The outer thin skin. This is more complex than the coverings of the Bean, for the grain of Corn is not merely a seed, but a one-seeded fruit, and the outer covering is made up not only of two seed-coats, but also of several layers belonging to the ovary or sack in which the seed is formed. Therefore the micropyle, rhaphe, chalaza, etc., are covered up, and the place where the grain was attached to the cob *does not correspond to the hilum.*

2. The lower firmer portion, the *embryo*.
3. The upper softer, more mealy portion, the *endosperm*, or food stored away for the use of the embryo when it begins to grow. *This part of the kernel of the Corn is lacking in the Pea and the Bean, where the food for the use of the embryo is all stored away in the thickened cotyledons.*
4. Examining the cut surface of the embryo, notice that the inner portion lying against the endosperm is solid and represents the *single cotyledon*.
5. The outer portion consists of two parts: an upper part of several pieces, one within the other (the *plumule*), and
6. A lower solid part (the *caulicle*).
7. Make a detail sketch of the cut surface and label carefully.

XII. Remove the embryo whole from a softened grain of Corn and notice:—

1. Its general shape.
2. The size of the cotyledon proportional to the rest of the embryo.
3. The plumule and caulicle, hidden from sight.
4. Sketch the embryo in different positions.

XIII. Examine a seed of the Onion and notice:—

1. That there is a notch at one end.
2. That there is a hole (the *micropyle*) on one side of the notch, and
3. A scar (the *hilum*) on the other.

XIV. Holding the seed between the thumb and first finger, cut it into two pieces, in a longitudinal plane passing

through both micropyle and hilum. Examine the cut surfaces with the lens and notice : —

1. The *seed-coats*.
2. The white, translucent *endosperm*.
3. The coiled *embryo*, lying within the endosperm.
4. Removing the embryo, examine it with the lens and notice that there are no distinct parts. The end towards the micropyle is the *caulicle*, the other is the *single cotyledon*.
5. Make sketches showing these points.

XV. Take a seed of the Piñon Pine and notice : —

1. Its size, shape, color, etc.
2. The *micropyle* at the narrower end.
3. Remove the thick shell, which in the Pine Seed represents the single *seed-coat* characteristic of this group of seeds and notice : —
4. The kernel.

XVI. Cut a longitudinal slit in the side of the kernel, and carefully split (by the aid of your thumb-nails) the kernel into two halves, thus exposing : —

1. The embryo in the centre surrounded by the firm white *endosperm*.
2. Study and sketch the embryo, noticing : —
3. The *caulicle*, straight and undivided, and
4. The several (6-11) narrow *cotyledons*.

XVII. Take the kernel of another seed and make a cross-section through the region of the cotyledons. Examine with the lens and make a sketch, noting : —

1. The ring of *endosperm*, enclosing
2. The *cotyledons*, arranged in a circle or *whorl*.

XVIII. In reviewing the work done upon seeds, fill out the blanks in a table copied into the note-books from the form on page 9.

XIX. **Questions about Seeds.**—The answers should be written out carefully in the note-books.

1. What are the essential parts of a seed (*i.e.* what parts *must* be present in order that any object can be called a seed)?
2. What is the embryo?
3. What are the parts of the embryo?
4. In what two ways is food stored away for the use of the embryo?
5. How do embryos differ from one another as regards the number of cotyledons?
6. Is the dry seed alive or dead? Give the reasons for your answer.
7. What characterizes the cotyledons which contain all the nourishment for the embryo?
8. Is the resting condition of the dry seed of any especial use to the plant? If so, of what use or uses may it be?
9. Why are the embryos folded up and packed away in so small a space?

CHAPTER II

SEEDLINGS

I. Take some Peas which are just beginning to sprout, and notice :—

1. What organ protrudes itself first from the seed-coats?
2. Make sketches showing this.

II. Take some sprouting Beans, notice the same point and make sketches.

III. Take some sprouting grains of Corn, notice the same point and make sketches.

IV. Take a pot of well-grown seedlings of the Pea and notice :—

1. The *position of the cotyledons* relative to the surface of the soil.

Dig up some of the seedlings carefully and notice :—

2. That the cotyledons remain closely pressed together and within the seed-coats.
3. That the caulicle remains short, but that
4. A fairly long root (a *primary root*) with branches has grown out and downward from its tip.
5. That the plumule has grown out from between the cotyledons and upwards into the light.

6. This elongated plumule consists of several joints (*nodes*), each bearing a *leaf* (or scale representing a leaf) and intervals between these (the *internodes*).
7. Make a sketch showing these different parts and label each carefully.

V. Take a pot of well-grown Bean Seedlings and notice :—

1. The *position of the cotyledons* relative to the surface of the soil.

Examine some seedlings which have been carefully removed from the soil and notice that :—

2. The cotyledons have cast off (as a general rule) the seed-coats and have separated from one another. In the older seedlings *they have become greenish*; and in the oldest seedlings of all they have dried up and fallen off.
3. The caulicle has elongated to many times its original length and has become stouter and green in color.
4. A stout main root (a *primary root*) with branches has grown from the tip of the caulicle.
5. The plumule has lengthened and consists of several nodes, internodes, and leaves.
6. The leaves borne upon the first node above the cotyledons number two, are on opposite sides of the node, and are different in size, shape, color, and texture from the cotyledons. They are also placed upon the stem at right angles to the cotyledons.
7. The second node above the cotyledons bears a single leaf, having its flattened portion (the *blade*) in three separate pieces instead of in one as in the cotyledons and the first pair of green leaves.
8. Make a sketch of the Bean Seedling showing these points.

VI. Examine several pots containing seedlings of the Castor Bean of various ages. Notice that : —

1. The caulicle first breaks through the surface of the soil and is bent into a "loop," both ends being still buried.
2. The "loop" increases in size and rises higher and higher until
3. At length the main body of the seed begins to break through the surface of the ground.
4. The outer seed-coat (*testa*) is usually left behind in the ground, but the inner seed-coat (*tegmen*) with the enclosed *endosperm* and *cotyledons* is pulled out of the ground by this action of the caulicle.
5. Older seedlings will show how the cotyledons gradually separate from one another *while still absorbing nourishment from the endosperm*, but —
6. They finally separate widely along their whole length, throwing off the tegmen and what is left of the endosperm, and are ready to do the work of leaves, *as is shown by their expanding and turning green*.
7. Make a series of sketches to illustrate these points.
8. Compare the cotyledons with one of the leaves of an adult plant of the Castor Bean as regards size, shape, color (of both surfaces), and venation (arrangement of the veins or ribs).

VII. Take a pot of fairly well grown seedlings of Indian Corn and notice that : —

1. The plumule, enwrapped in the tip of the cotyledon, is the first part of the seed to appear above the ground.

Examine a seedling which has been carefully removed from the earth and notice that : —

2. The cotyledon remains within the seed-coats closely applied to the *endosperm*, which becomes semi-fluid and milky, is gradually absorbed by the cotyledon (acting as a sort of sucker) and transferred to the growing parts, which are : —
3. The *primary root or roots*, arising from the tip or sides of the *caulicle*, which lengthens very little, and
4. The elongated *plumule*, which consists of nodes, each bearing a single grass-like leaf, and short internodes.
5. Notice that roots are also given off just above the cotyledon and from the nodes of the plumule. These are *adventitious roots*. The difference between adventitious and primary roots is, that the primary roots grow from the caulicle, *i.e. originate below the cotyledons*, while adventitious roots *originate above the cotyledons*.
6. Sketch a seedling of the Indian Corn, showing these points.

VIII. Examine several pots of Onion Seedlings of various ages and notice : —

1. The green loops just appearing above the ground and becoming larger until they pull the *seed-coats* and the *endosperm* out of the ground.

The examination of seedlings which have been carefully removed from the soil, shows that : —

2. The green loop is in each case the *single cotyledon* which, by its elongation, has pushed the short caulicle out from the seed-coats and has finally pulled the seed-coats and endosperm from the ground, while

3. The short *caulicle* has not lengthened at all, but has given rise to one or more *primary roots* from its tip.
4. Very old seedlings will show the tip of the cotyledon withering away and losing the now emptied seed-coats, while the plumule emerges from a longitudinal slit at the base.
5. Make a series of sketches to show these points.

IX. Take some Pine Seedlings (of different ages if possible) and notice that : —

1. The lengthening caulicle bends to form a loop and pulls the cotyledons with the *seed-coat* and *endosperm* out of the ground. (This does not always happen, however, in the species with large seeds or “nuts.”)
2. The spreading cotyledons cast off the seed-coats and expand to form a circle or whorl of needle-shaped leaves.
3. The *plumule* appears only after some time has gone by.
4. Make a series of sketches to show these points.

X. In order that an ordinary seed may germinate, it is placed usually in a light soil whose particles have been loosened, well watered, and kept warm. We may infer from this that *access of air, water, and a sufficiently high temperature* are necessary.

1. Place dry Peas in dry, loose sawdust, add no water, keep in a warm place, and watch several days, after which uncover the Peas and examine to see whether any changes have taken place.
2. Place dry Peas in dry, loose sawdust, occasionally sprinkle well with water, keep in a warm place, watch, and examine as in (1).

3. Place dry Peas in dry, loose sawdust, occasionally sprinkle well with water, keep in the refrigerator at a low temperature, watch, and examine as in (1),
4. Make careful notes of any differences observed as regards the behavior of the three sets of peas from day to day.

XI. Questions for Summary and Review.

1. What part of the embryo protrudes first from the seed-coats?
2. In what plants does the caulicle form a loop and appear above the ground first?
3. In what plants does the cotyledon form a loop and appear above the ground first?
4. In what plants do the cotyledons emerge from the ground?
5. In what plants do the cotyledons remain below the surface of the ground?
6. In what plants do the cotyledons bring the endosperm up above the ground?
7. In what plant does the cotyledon remain below the ground absorbing nourishment from the endosperm?
8. In what plants does the plumule appear above the ground first?
9. In what plants does the caulicle lengthen considerably?
10. In what plants does it remain short?
11. In what plants do the cotyledons turn green, live for some time, and act like ordinary leaves?
12. In what plants does the plumule grow out promptly?
13. In what plants does it grow out only after some time?
14. What reasons can you give for the different shapes of the cotyledons in different plants?
15. Why are they different from the adult leaves of the same plant?

CHAPTER III

ROOTS

I. Examine the root of a well-grown plant of the Bean and notice that : —

1. It is a single *main* root. We know from our previous study (cf. Chapter II, § V, 4) that it is a *primary root*. A single, persistent, primary root, such as this of the Bean, is called a *tap root*.
2. From the sides of the primary root are given off branches growing obliquely outwards. These are *secondary roots*. They in turn give rise to *tertiary roots*, etc.
3. There are no nodes and internodes on these roots.
4. All the roots grow more or less downwards and away from the light.
5. Make a sketch showing these points.

II. Examine the roots of a well-grown seedling of the Squash and notice that : —

1. The several roots all spring from near the same point at the base of the elongated caulicle. Such roots as these are called *multiple primary roots*, as distinguished from the single primary root of the Bean.
- 2, 3, 4, and 5 as in I.

III. **Adventitious roots** have already been examined in the seedlings of Indian Corn. Examine the base of an adult Corn Stalk and notice that :—

1. The *primary roots* have disappeared long ago.
2. Each of the lower nodes of the “stalk” or stem bears a circle of *secondary roots*, extending out obliquely downwards, and as the nodes and roots die away below, new secondary roots are formed at the nodes above.
3. Make a sketch showing these points.
4. Why does the farmer “hill up” the Corn?

IV. **Root Hairs.**—Examine the roots of the Pea, Bean, and Corn, grown in loose, damp sawdust (or in a moist chamber), with a lens. Notice and sketch the root hairs. Upon what portions of the roots do they occur? Of what use are they to the plant?

V. **Summary and Questions.**

1. Of what two principal uses are the ordinary (or *typical*) roots to the plant?
2. Why do we water the roots of the plants?
3. Why are fertilizers placed about plants or in the soil in which seeds are sown or plants are planted?
4. Why do the roots spread out below ground?
5. What are the differences between primary and secondary roots?
6. What are the differences between primary and adventitious roots?
7. What is a tap root?
8. What are multiple primary roots?

CHAPTER IV

STEMS

I. Take a piece of Sunflower stem, several inches long, examine and notice :—

1. The regular succession of *nodes* and *internodes*. (For definitions turn back to § IV, 6, under Seedlings, p. 12.)
2. The consistency of the stem (in this case not very woody).
3. How long does the Sunflower stem live?
4. The Sunflower is an *herb* and its stem is said to be *herbaceous*. Why? *Texture a herbaceous*
5. Make a sketch of this piece of stem. *Not woody*

II. Examine a thin section of the Sunflower stem, cut transversely. (These sections are best, if prepared by the teacher and examined under the lens of the dissecting microscope, or under the lower power of a compound microscope.) Notice :—

1. The central softer portion, the *pith*, made up of larger or smaller polygonal spaces, the *cells*.
2. The ring of rather irregularly shaped bodies surrounding the pith, the *woody* or *vascular bundles*.
3. The *outer bark* or *cortex*, including everything outside of the vascular bundles, except

4. The very outermost skin-like layer, the *epidermis*.
(This, in the Sunflower, is rough, with hair-like outgrowths.)
5. Make a sketch or diagram to show the arrangement of these parts.

III. Examine one vascular bundle carefully and notice : —

1. The inner porous portion, the *woody portion* or *xylem*.
2. The outer denser portion, the *hard bast*.
3. The central portion, a band-like layer, which under the higher powers of the compound microscope may be seen to consist of two parts.
 - (a) the *cambium* or actively growing portion, a narrow layer next the xylem, and
 - (b) The *soft bast* or *phloem*, occupying the greater part of this region and lying toward the hard bast. (The hard bast makes up that part of the stem known as the inner bark.)

IV. The parts of the Sunflower stem are : —

$\left\{ \begin{array}{l} \text{Pith.} \\ \text{Vascular bundles,} \\ \text{Cortex.} \\ \text{Epidermis.} \end{array} \right.$	$\left\{ \begin{array}{l} \text{xylem or wood.} \\ \text{cambium.} \\ \text{bast,} \end{array} \right.$	$\left\{ \begin{array}{l} \text{soft bast or phloem.} \\ \text{hard bast.} \end{array} \right.$

V. Take from half to three-quarters of an inch of an internode of Sunflower stem, and with a sharp scalpel or penknife blade, scrape away carefully the epidermis and cortex, exposing : —

1. The *vascular bundles*. Notice their longitudinal course and the fact that they run parallel to one another.

2. Detach one or two of the vascular bundles at one end and peel them away from the pith. Notice the fibrous character of the bundle. (Very frequently the hard bast is the only portion which will come away from the pith.)
3. Test the strength of a vascular bundle as compared with a piece of the pith.
4. Make a sketch with notes to record these points.

VI. The Sunflower stem is a good type of an *exogenous stem*, or one which has the vascular bundles arranged in a cylinder about a central pith. (In some plants the pith disappears during growth and the stem becomes hollow.) Plants with exogenous stems have *netted-veined leaves*, *di- or poly-cotyledonous embryos* and the *parts of the flower usually arranged in fours or fives*.

VII. Take a piece of the stem of Indian Corn several inches long, examine carefully and notice :—

1. The regular succession of nodes and internodes.
2. The consistency of the stem (see § I, 2, of this chapter).
3. How long does the Corn stem live?
4. Is it herbaceous or not? (see § I, 4, of this chapter).
5. Make a sketch of this piece of stem, representing and labelling the parts.

VIII. Examine a thin transverse section of the stem of Indian Corn in the way indicated in paragraph II of this chapter. Notice :—

1. The *vascular bundles*. These are *scattered through the pith*, leaving no central portion free.
2. The outer bundles are placed closer together and approach the outer edge very closely, but there is

3. An outer dense layer, the *rind*. What is this rind for?
4. Make a sketch of the section to show these points.

IX. Take several inches of an internode of the stem of Indian Corn, cut a thin slice lengthwise from the middle, hold it up to the light, examine with the lens, and notice : —

1. The vascular bundles pursue direct longitudinal courses through the pithy portion and are approximately parallel.
2. Make a sketch or diagram to show this.

X. The stem of Indian Corn is a good type of an *endogenous stem*, or one which has the vascular bundles distributed fairly uniformly through the pith and not forming a cylinder outside it. Plants with endogenous stems, usually have *parallel-veined leaves*, *monocotyledonous embryos* and the *parts of the flower arranged in threes*.

XI. Take a piece of a Walnut or Butternut about a foot long and notice : —

1. The regular succession of nodes and internodes.
2. The consistency of the stem (see § I, 2, of this chapter).
3. How long does the stem of the Walnut or Butternut live? (see § I, 4, of this chapter). Plants with considerable wood and which remain from year to year without dying down to the ground (as the Sunflower and Indian Corn do) are either *shrubs* or *trees*.

A *shrub* is smaller than a *tree* and does not usually possess a distinct trunk. Give some examples.

The stem of a shrub is said to be *fruticose*, *suffrutescent* or *suffrutescent*. How do the stems to which these terms are applied, differ from one another?

Woody above ground. Below ground is the root system. The stem of a shrub is said to be fruticose, suffrutescent or suffrutescent. How do the stems to which these terms are applied, differ from one another?

The stem of a tree is said to be either *arboreus* or *arborescent*. What is the difference?

Tree like

from a stem like trunk

XII. Examine the surface of a branch of Walnut or Butternut which has been cut across with a sharp knife (or razor), and with the aid of the lens notice:—

1. The *central pith*.
2. The *ring* (or *rings*—notice the number in different twigs) of *wood (xylem)* about the pith.
3. The fine white lines radiating out from the pith through the wood. These are the *medullary rays*.
4. Outside the rings of wood, a narrow whitish ring, the inner part of which is the *cambium*, the outer part the *soft bast*.
5. Outside of this a ring of dots, the *hard bast*.
6. Then a fairly wide, yellowish green ring, the *cortex*, and finally
7. A narrow brown ring, the *corky bark*.
8. Make a sketch, representing and labelling the parts.

XIII. 1. Is the stem just studied, *exogenous* or *endogenous*? Why?

2. How old was the branch you were studying?
3. How may we tell the age of a tree?
4. Can you name any tree or trees possessing the other kind of stem?
5. The trunk and branches of exogenous trees *increase in girth* through the activity of the *cambium* ring which forms new wood or *xylem* on the inner side and new bast or *phloem* on the outer side. Most *endogenous* stems, having no cambium ring, do not increase very much in girth.

XIV. Reviewing the work done upon both roots and stems, write the answers to the following questions in your note-book :—

1. What differences exist between the growth of roots and stems as regards gravity?
2. What differences as regards light?
3. What differences as regards the possession of leaves?
4. What differences as regards nodes and internodes?
5. How, then, may we always tell a stem from a root?

XV. Considering the different stems studied and examined, either in connection with the book or in addition to those mentioned there, answer the following :—

1. How do we classify stems according to their structure?
2. How do we classify stems according to their consistency and duration?
3. In what different directions may stems (*i.e.* those above the ground) grow?

XVI. Having considered the structure of several different characteristic stems, we may examine them to see of what service the stem is to the plant. We notice: (1) that the upper part of the stem bears the leaves and carries them up into the light and air; (2) that the lower part bears the roots which make their way down into the ground.

The stem serves not only to support the leaves, but also as a pathway by which whatever the roots absorb from the earth may be transported to the leaves — and also for the transfer of whatever the leaves may manufacture to the roots; in other words, it connects these two important sets of organs.

What is the function of the stem?

CHAPTER V

LEAVES. I

apple, pear

I. Take a piece of stem of the Japanese Quince which has several leaves attached to it. Examine the leaves and notice that : —

1. They are all borne on the sides of the stem (*i.e.* that they are *lateral structures*).
2. They are broad and thin (*i.e.* they are also *expanded structures*).
3. Their color is *green*. (This is not true for all leaves, *e.g.* examine the leaves of some common red *Coleus* of the garden or greenhouse, in which another coloring-matter is present and hides the green.)
4. They are borne at the *nodes* of the stem. (We may consequently separate that portion of the plant above the root into a number of similar parts, each of which may be called a *phytomer* or plant part. Each phytomer will consist of an *internode*, and a *node* with its *leaf* or *leaves*. Sketch a phytomer of the Japanese Quince and label it.)
5. They grow only to be of a certain size and then stop (being ~~un~~like stems or branches in this respect).
6. Notice that each leaf has a small *bud* in its *axil*, *i.e.* in the angle between its upper surface and the stem.
7. We may define a leaf as being *an expanded, lateral structure of limited growth, borne on the stem and usually*

with a bud (or branch) in its axil. (This definition, while a good working definition, will not apply in a few exceptional cases. But the same thing will be found true of almost any definition of any natural object.)

8. Make a sketch to show these points.

II. Remove one leaf carefully so as to retain all the parts, and notice : —

1. The broad expanded portion, the *blade* or *lamina*. Notice its outline.
2. The slender stalk or *petiole*.
3. The pair of small expanded structures, the *stipules*, at the base of the petiole.
4. Make a sketch to show these parts and label carefully.
5. This leaf is a good type of a *simple leaf* (*i.e.* of a leaf with a single blade) having all the three parts represented; viz. *blade, petiole, and stipules*.

III. Examine the blade of the leaf of the Japanese Quince (or better, that of some thinner leaf such as the Mock Orange or the Pittosporum) and notice the *venation* or method of arrangement of the veins or ribs.

1. A prominent *midrib*.
2. Side veins or ribs running outward toward the edge and obliquely upwards.
3. These in turn branch, and then these branches branch again, and so on, the finer branches *anastomosing* or joining to form a fine network. Such a leaf as this is said to be *netted-veined*.
4. Make a sketch to illustrate this.

IV. Take a leaf of the common "English Ivy," which is also netted-veined, and compare it with the one just studied, noting the similarities and differences. Notice also : —

1. The different shape of the leaf blade. It is said to be *palmately-lobed*.
2. Make a rough sketch.

V. Take a leaf of the Lily of the Valley and study the venation, noticing : —

1. The central stouter vein.
2. The other veins running approximately parallel to it.
3. The absence of conspicuous anastomosing veins to form a network.
4. Such a leaf as that of the Lily of the Valley is said to be *parallel-veined*.
5. Make a sketch to show this kind of venation.

VI. Take a leaf of the Calla Lily and study the venation. Notice : —

1. The central vein or rib.
2. The side veins running out from it.
3. This leaf is also said to be *parallel-veined* and represents simply a different arrangement.
4. Draw a sketch to illustrate this method of venation.

VII. *Netted-veined* leaves are usually associated with *exogenous stems*, *dicotyledonous embryos*, and the *parts of the flower arranged in fours or fives*.

Parallel-veined leaves are usually associated with *endogenous stems*, *monocotyledonous embryos*, and the *parts of the*

flower arranged in threes. (See also §§ VI and X of the preceding chapter.)

VIII. Take a leaf of the Five-Finger (or the Garden Strawberry), examine carefully, and notice : —

1. The *stipules*.
2. The *petiole*.
3. The *blade* composed of several pieces or *leaflets* (3 to 8).
4. Make a sketch to show these parts.

IX. The leaf just studied is called a *compound leaf*, because the blade consists of more than one piece. It is also called a *palmately compound* leaf because the leaflets radiate out from one point, as the fingers do from the palm of the hand.

X. Take a Rose leaf, examine, and notice : —

1. The *stipules*.
2. The *petiole*.
3. The *compound* nature of the blade consisting of several leaflets.
4. The differences between this and the last leaf studied, as regards the position of the leaflets ; viz. that in the Rose they arise from different points along what corresponds to the midrib of the simple blade.
5. Such a leaf as that of the Rose is said to be *pinnately* (from *pinna*, a feather) *compound*.
6. Make a sketch of the Rose leaf.

XI. Examine a Parsley leaf and notice : —

1. That it is several times compound, or *decompound*.
2. That the parts are arranged in a *palmate* fashion.
3. Sketch.

XII. Take as many different simple leaves as you can. Examine them as regards the following points : —

1. *Parts present or absent ; i.e.* blade, petiole, and stipules.
2. *General outline of the blade.*

In this respect they may be classified as follows : —

- (a) Of the same width throughout = *linear* or *oblong*.
- (b) Broadest at the base = *lanceolate*, *ovate*, or *ovate-lanceolate*.
- (c) Broadest at the middle = *elliptical*, *oval*, or *orbicular*.
- (d) Broadest at the apex = *spatulate*, *oblanceolate*, *obovate*, or *cuneate*.
- (e) Special shape of the base, *e.g.* : —
cordate, *reniform*, *auriculate*, *sagittate*, *hastate*, or *peltate*.
- (f) Special shape of apex, *e.g.* : —
(*) pointed = *acuminate*, *acute*, *cuspidate*, *mucronate*, or *aristate*.
(**) blunt = *obtuse* or *truncate*.
(***) notched = *retuse*, *emarginate*, or *obcordate*.
- (g) Character of margin = *entire*, *serrulate*, *serrate*, *denticulate*, *dentate*, *crenate*, *undulate*, *lobed*, *cleft*, *parted*, or *divided*.
- (h) Character of the surfaces = *smooth*, *glabrous*, *glaucous*, *rugose*, *scabrous*, *pubescent*, *tomentose*, *sericeous*, *pilose*, *hirsute*, *hispid*, etc.

XIII. Take a piece of the leaf of a Calla Lily and study its structure.

1. With a scalpel or blade of a penknife strip off a piece of the transparent outer skin or *epidermis*.

2. Examine the *green pulpy material* thus laid bare and notice —
3. That it is spread out upon a *woody framework* composed of the veins.

XIV. Examine a bit of the *Calla* leaf with the lens and notice the numerous small dots upon its surface. These are the *stomata*, or *breathing pores*, through which an interchange of gases goes on between the outside air and the small spaces in the green pulp of the leaf. (A single *stoma* may be studied by examining a small piece of the epidermis under the lenses of a compound microscope.)

XV. The services rendered a plant by its ordinary, or *foliage* leaves cannot readily be inferred without careful experiment. We notice, however, that the plant sends up its leaves into the air and sunshine. We notice, also, that leaves developed in the dark (as *e.g.* on potatoes in the cellar) are pale yellow, but become green again if placed in the light. We conclude that the leaves need air and sunshine to do their proper work. The existence of breathing pores helps us to understand that the leaves are *gas-absorbing organs*; that is, that they take something (in this case carbonic acid gas) from the air, and in their turn give something back (in this case oxygen). It can be demonstrated that water, in the form of vapor, escapes from the leaf, and that this loss must be made good by the stem giving up some of its water, and the stem, in turn, receives water from the roots. In this way a *current of water* is helped to move from the roots up through the stem into the leaves.

The water thus obtained contains, dissolved in it, small quantities of various substances, parts of which are combined

in the leaves, with the carbon of the carbonic acid gas absorbed from the air, and from these various elements thus obtained are manufactured, partly in the leaves and partly elsewhere in the plant, all the plant substance.

The leaves, then, are what we may call *absorbing*, *excreting*, and *assimilating* organs: *absorbing*, because they take up gases from the atmosphere; *excreting*, because they get rid of the superfluous water and oxygen gas; and *assimilating*, because they take substances unlike plant substance and manufacture them into plant substance itself, in order to repair the "wear and tear" of the various parts of the plant and in order to furnish material for the formation of new parts.

XVI. Questions about Leaves.

1. What is a leaf?
2. What are the parts of a typical leaf?
3. What is the difference between a simple and a compound leaf?
4. What is meant by venation?
5. What is a netted-veined leaf?
6. What is a parallel-veined leaf?
7. What is the difference between a pinnately and a palmately compound leaf?
8. Describe the differences between the two types of netted-veined leaves.
9. Describe the differences between the two types of parallel-veined leaves.
10. When is a leaf said to be decompound?
11. What three sets of things make up the substance of a leaf?
12. Describe the epidermis.
13. Describe the green pulp.

14. Describe the woody framework.
15. Why is a leaf an expanded structure?
16. Why does it need air and sunlight?
17. What would happen to a plant if it were kept stripped of its leaves? Why?

CHAPTER VI

LEAVES. II

THE several leaves studied in the last chapter were, we may say, typical foliage leaves. They all possessed distinct blades and petioles, and most of them possessed stipules. The blades also possessed distinct upper and distinct lower surfaces. The leaves to be studied in this chapter differ from typical leaves while still serving as foliage.

I. Take a piece of the stem of a *Chrysanthemum* bearing several leaves and notice : —

1. That the leaf blades are attached directly to the stem, there being no petiole. Such a leaf is said to be *sessile* or “sitting.”
2. The general shape, shape of apex, etc.
3. The venation.
4. Make a sketch.

II. Examine the leaf of the Bellwort (*Uvularia perfoliata*) and notice : —

1. The general shape, etc.
2. The venation.
3. The absence of petiole and stipules.
4. The clasping base completely encircling the stem. Such a leaf is said to be *perfoliate*.
5. Make a sketch to show these characters.

III. Examine a flowering branch of one of the true Honeysuckles and notice that : —

1. The lower leaves are in pairs and entirely separate.
2. The leaves toward the end of the branch are also in pairs and are sometimes united around the stem by the growing together of their bases.
3. The uppermost pair are grown completely together.
4. Such leaves as these uppermost ones are said to be *connate-perfoliate*.
5. Make a sketch of the branch and the various pairs of leaves to show these characters.

IV. Examine an *Acacia* leaf (not an *Acacia* with the compound leaves, but one with what appear to be simple leaves) and notice : —

1. The general shape.
2. The venation.
3. The position upon the stem. It is attached to the stem in such a way that its edges point up and down, *i.e.* it is *vertical* in position.
4. This vertical attachment shows that it is really a petiole (without any blade at all) very much flattened, serving the purpose of a blade. Such structures are called *phyllodia*. (An additional proof that these phyllodia are flattened petioles is afforded by the fact that seedlings of the phyllodia-bearing *Acacias* usually have the first few phyllodia bearing regular compound blades at their tips.)
5. Make a sketch to show the phyllodia.

V. We have studied leaves without stipules, leaves without either petioles or stipules, and leaves consisting only

of a flattened petiole without a blade. If a specimen of *Lathyrus Aphaca* (either fresh or pressed) can be obtained, examine its leaves and notice :—

1. The absence of blades ;
2. The prolongation of the petioles into tendrils ; and
3. The increase in size of the stipules (to make up for the loss of the blade).
4. Make a sketch of one leaf.

VI. Many plants have leaves without distinction of parts ;
e.g. examine and sketch :—

1. The needle-shaped leaves of a Norway Spruce or a Pine.
2. The awl-shaped and scale-shaped leaves of the Arbor-Vitæ or the Lawson's Cypress.

VII. Examine a rootstock of Iris to which the leaves are attached. Notice that :—

1. Each leaf stands erect and presents its tip to the sky.
How does this compare with the ordinary leaves?
2. Each leaf is folded together lengthwise so that the upper surface (or what corresponds to it) is inside.
3. Make a sketch.

VIII. Examine one of the upper leaves of a *Eucalyptus*. Notice that :—

1. The two surfaces are vertical (instead of horizontal).
2. This is brought about by a twisting of the petiole.
3. Examine the leaf of a young *Eucalyptus* and notice that it has a horizontal position instead of a vertical one.
4. What are the reasons for these two positions?
5. Sketch each leaf to show its position.

IX. Examine a piece of the so-called Smilax (*Myrsiphyllum*) and notice : —

1. The slender stem.
2. The expanded leaf-like structures. Notice their shape and venation.
3. The delicate scale at the base of each of these leaf-like structures. This scale is the *true leaf*, and the expanded structure in its axil (see § I, 7, of Chapter V) is a branch flattened to serve as a leaf. A branch structure modified thus is called a *cladophyllum* (plural is *cladophylla*).
4. Make a sketch of one *cladophyllum*, its subtending *scale-like leaf* and the piece of stem upon which it is borne.

X. Examine some plants which have been grown before a window (and consequently strongly lighted from one side). Notice : —

1. That the leaves present their upper surfaces to the light.
2. Turn the plants around and notice, after a day or two, that the leaves have turned so that their upper surfaces are again directed toward the light.

XI. Examine a plant of some species of *Oxalis* and notice : —

1. The trifoliate, palmately compound leaves.
2. The position of the leaflets during the day-time.
3. The position of the leaflets during the night-time.
4. Sketch both positions.
5. What causes the so-called "sleep" of plants?

XII. Examine a Sensitive Plant and notice : —

1. The character of the expanded undisturbed leaf. Sketch.

2. The method of folding together the parts of a leaf after it has been touched. Sketch.
3. The time elapsing, after touching, before it begins to fold together.
4. The time elapsing before the parts are completely folded together.
5. Make sketches to show these changes.
6. How long does it require to open again?

XIII. Examine the leaf of the Orange (or of the Barberry of New England) and notice : —

1. That the stalk is flattened and jointed at the insertion of
2. The blade.
3. Make a sketch to show this.
4. This joint indicates that the "blade" answers to a leaflet of a compound leaf, and if we examine some of the nearly related Barberries or members of the Orange family, we shall find that the leaves are *pinnately compound* with several leaflets. Such a leaf as the one studied is called a *unifoliolate compound leaf* and it is considered that the side leaflets have failed to develop.

XIV. Longevity of Leaves.

1. How long (*i.e.* how many months) do the leaves of the Willows, the Maples, or the Elms live?
2. How long do the leaves of the Live-oaks live? (Take a piece of stem with the oldest leaves you can find, cut it across, and count the rings.)
3. How long do the leaves of the Norway Spruce, the various Pines, or Cypressess live?

XV. **Defoliation or the Fall of the Leaf.** — Examine various leaves as they are falling or after they have fallen and notice how they separate from the branch which bore them.

1. The Willows, Elms, Maples, Alders, and Hazels. The leaves separate from the stem at the base of the petiole and fall off, leaving a clean scar. *This is characteristic for simple leaves.*
2. The Rose or the Locust-Tree, having pinnately compound leaves. The leaflets usually fall away first, leaving the petiole and axis, and this falls later, separating from the stem at the base of the petiole.
3. The Horse-Chestnut or the Buckeye, having palmately compound leaves, may behave in either of two ways.
 - (a) The whole leaf may separate at the base of the petiole and fall ; and then the leaflets fall away from the apex of the petiole ; or
 - (b) The leaflets may fall away from the petiole while it is still attached to the tree, the petiole itself falling afterward.
4. It may be seen that the blade does not separate from the petiole in simple leaves, but does in compound leaves.
5. Notice that the blade of the leaf of the Grape Vine, or of the Japanese Creeper, falls away from the petiole. This shows that the apparently simple leaf of the Grape Vine, or of the Japanese Creeper, partakes of the nature of a compound leaf. (Some nearly related vines and creepers have compound leaves, and some of the leaves of the Japanese Creeper may be compound.)
6. Make sketches and notes.

CHAPTER VII

PHYLLOTAXY

PHYLLOTAXY is the arrangement of leaves upon the stem. Leaves are arranged upon the stem in one of two ways as illustrated by Fuchsia (§ I) and by Begonia (§ IV)

I. Examine a branch of some species of Fuchsia and notice : —

1. The number of leaves at each node.
2. The relative arrangement of the leaves at two successive nodes.
3. Make a sketch to show these points.
4. The arrangement of leaves just studied is a good example of the *opposite or cyclical arrangement*.

II. Look at the branch of Fuchsia from above and notice : —

1. The four *vertical ranks* of leaves.
2. Make a diagram to represent this.

III. Examine a plant of the common Bedstraw or Cleavers (species of *Galium*) and notice : —

1. The number of leaves (3 to 8 or 10) at each node.
2. The relative arrangement of the leaves at two successive nodes.

3. Look at a branch from above and notice the number of vertical ranks.
4. Make sketches.
5. This is also an example of the *cyclical arrangement*. When there are more than two leaves arranged in a circle about a node, it is said to be a *whorl*.

IV. Examine a branch of some species of *Begonia* having a conspicuous stem above ground. Notice :—

1. The number of leaves at each node.
2. The relative position of the leaves at two successive nodes.
3. Draw a line from one leaf to the next, winding around the stem, and continue this line in a direct curve to the next, and so on, until a leaf is reached directly above (*i.e.* vertically) the one from which the line starts. Notice :—
4. That this line is a spiral.
5. The number of leaves through whose bases it passes before it arrives at the leaf immediately above the one from which we started. (In this we count the leaf at which we start, but not the one at which we end.)
6. The number of turns of the spiral.
7. Make a sketch or diagram to show this spiral.
8. The *Begonia* illustrates what is known as the *spiral arrangement*. (Compare it with the *cyclical*.)

V. If we view the stem and leaves of the *Begonia* from above, we shall see that the leaves are arranged not only in this one *spiral rank*, but also in *vertical ranks* (see also §§ II and III, 3). Notice that, in this case, there are two vertical ranks. For this reason such an arrangement as this is called a *two-ranked arrangement*.

VI. It is found very convenient to represent any of the *alternate or spiral arrangement* of leaves such as the Begonia by a common fraction. The number of *turns of the spiral* is taken for the *numerator*, and the *number of leaves* passed through for the *denominator*. What would be the fraction for the Begonia?

VII. Take a young plant of the White Hellebore (*Veratrum viride*) and notice : —

1. The *three vertical ranks*.
2. That the spiral makes one revolution and passes through three leaves before it reaches the one directly above the one from which it started.
3. What fraction will express the phyllotaxy of this *three-ranked arrangement*?
4. Make sketches of the White Hellebore, including views from the side and from above.

VIII. Examine the arrangement of the leaves upon a vertical branch of the Apple or Pear Tree, noticing : —

1. The number of leaves at each node.
2. The number of leaf-insertions passed through to reach one exactly above the one from which you start.
3. The number of revolutions of the spiral.
4. Make a diagram to show this.
5. What is the fraction representing this arrangement?
6. What should the number of vertical ranks be?
7. Do you notice any twisting of the internodes so as to make the determination of the phyllotaxy difficult?

IX. Examine a vertical branch of Holly or of Pittosporum

1. Find the number of vertical ranks.

2. The number of leaves through which the spiral passes to the leaf directly above the initial leaf.
3. The number of revolutions of the spiral.
4. The fraction expressing the phyllotaxy.

X. Arrange the fractions found thus far in a series, and notice that we may determine the third one found, by adding together the numerators of the first and second to make its numerator, and the denominators of the first and second to make its denominator. Notice also that the fourth may be formed in the same way from the second and third.

What would be the fifth, sixth, etc., of this series?

XI. Examine a cone of the Norway Spruce or of some species of Pine. Notice :—

1. The scales of the cone (being really modified leaves) are closely packed together, and it is difficult to determine the original spiral.
2. Two series of *secondary spirals*, however, appear, one series running from left to right, and the other series from right to left.
3. Count the number of secondary spirals running from left to right.
4. Count the number of spirals running from right to left.
5. Beginning with some scale near the base, number (in ink) this scale 1.
6. Number the next scale in the same secondary spiral running to the right 1 plus the number found in 3, the next one this number plus the number found in 3, and so on.
7. Beginning again with scale number 1, number the next scale in the secondary spiral running to the left 1 plus the number of spirals found in 4, and so on.

8. Continue this numbering, beginning with any numbered scale, until the majority of the scales of the cone are numbered.
9. Take the scale next above scale number 1 in a vertical line, subtract 1 from the number upon this scale, and the result will be the number of leaves passed through in going from one leaf to the one directly above the one from which we started. This, of course, will be the denominator of the fraction.
10. Verify this number several times, taking other numbered scales for starting-points. (The accuracy of this method may be proven upon cones with few scales such as those of the American Larch.)
11. The numerator will be the smaller number of secondary spirals.

XII. Examine all the cones of different kinds you can get, and determine the phyllotaxy of each. In this way, arrangements represented by the fractions $\frac{3}{8}$, $\frac{5}{13}$, and $\frac{8}{21}$ may be found, and sometimes $\frac{13}{4}$ and $\frac{21}{5}$ may be made out.

Compare these fractions in the same way as in § X.

XIII. Examine an erect branch of some species of Maple and notice : —

1. The regularly opposite leaves.
2. That the pairs of leaves upon adjacent nodes are *decussate*, *i.e.* are at right angles to one another.
3. The petioles of both leaves in each pair are equal or very nearly so.
4. Look down upon the top of the stem and notice the four regular vertical ranks.
5. Make sketches to show these points.

XIV. Compare with the preceding the arrangement of leaves upon a branch of the same Maple which has grown out in a horizontal direction. Notice that :—

1. The leaves are also opposite.
2. They do not decussate, for the internodes are twisted.
3. The petioles in the different pairs are very unequal ; while that of one leaf remains short, that of the other often becomes very long to carry its leaf blade out from under some other leaf blade, in order to obtain its share of light and air.
4. The effect thus produced (when seen from above) of a green surface, made up of leaf blades fitted together, is called a *leaf mosaic*.
5. Make a sketch to show this.
6. Notice the same thing in the phyllotaxy of the horizontal branches of other trees.

XV. **Twisting or Torsion of the Internodes** has been noticed in one or two cases. This tends to make it difficult to determine the phyllotaxy by bringing the leaves away from their proper positions. It is usually seen best upon horizontal branches of the *Forsythia* or of young *Eucalyptus* trees. Notice :—

1. The opposite leaves.
2. They are arranged very nearly in two ranks.
3. Each internode, as shown by the lines or angles, is twisted through a right angle.
4. Make a sketch to show this.

XVI. Sometimes vertical ranks of leaves are made spiral by such torsion of the internodes.

Examine the *Pandanus* or Screw Pine of the conservatories and notice :—

1. The three ranks of sessile leaves.
2. The very short internodes.
3. The spiral course of each rank.
4. This seems, at least, an entirely different thing from the secondary spirals of the cones we have examined.

XVII. Examine branches of some species of Pine and of the Larch or Deodar and notice : —

1. The leaves, arranged in small bunches or *fascicles*. (Two to five in the Pines, a larger number in the Larch and Deodar.)
2. These leaves really belong to short branches whose internodes are so short as not to be visible.
3. Make sketches of these *fasciculate* leaves.

XVIII. Questions upon Phyllotaxy.

1. What is phyllotaxy?
2. In what two different sets of ways may leaves be arranged upon the stem?
3. What name do we give to each? Why?
4. Describe some varieties of the cyclical arrangement.
5. What is meant by the spiral arrangement?
6. How may any spiral arrangement be expressed in the form of a fraction?
7. Give the series beginning $\frac{1}{2}$, $\frac{1}{3}$, etc.
8. How does torsion of the internodes affect the phyllotaxy?
9. Describe the differences between the arrangement upon vertical and upon horizontal branches.
10. What is meant by fasciculate leaves? Give and explain examples.
11. Why should there be such a variety in the phyllotaxy of the different plants?

CHAPTER VIII

BUDS

I. BUDS may be defined as *incipient shoots*. What does this mean ?

II. Examine a leafless branch of Beech, Birch, or Alder, and notice the buds.

1. There is a single *terminal* bud.
2. The rest of the buds are *lateral*, *i.e.* situated upon the sides of the stem.
3. The lateral buds are placed *just above a leaf-scar*, so that they occupy the vertex of the angle formed by the junction of the leaf with the stem. This angle is called the *axil* of the leaf and such buds are called *axillary buds*.
4. Sketch a portion of the branch so as to show both *axillary* and *terminal* buds ; and notice that the terminal bud does not exceed the axillary buds very much in size.

III. Examine a leafless branch of Walnut or Butternut and notice the buds.

1. The *terminal bud* is larger than the lateral buds.
2. There are several (2-4) buds above each leaf-scar.
3. The one directly in the axil, *i.e.* nearest the leaf-scar, is usually very small. This is the *axillary bud*.

4. The buds above it are larger. They are called *accessory buds* (i.e. additional buds). They are also said to be *superposed* (i.e. placed one above the other).
5. The Walnut and Butternut, therefore, have three kinds of buds as classified by position: 1, *terminal buds*; 2, *axillary buds*, and 3, *superposed accessory buds*.

IV. What difference does this make as regards the branching of the Walnut or Butternut Tree ?

V. Examine a leafless branch of the Maple and notice the buds.

1. The large terminal bud.
2. The upper lateral buds, in threes, above the leaf-scars.
Distinguish
3. The middle *axillary bud*.
4. The *accessory* bud at each side.
5. The accessory buds of the Maple, being arranged side by side with the axillary buds in a horizontal line, are called *collateral accessory buds*.
6. Make a sketch to show the collateral accessory buds.

VI. Examine the terminal buds of the Buckeye or any of those of the Currant. (They are in best condition for this when just bursting open in the spring.) Notice :—

1. The overlapping brown scales which cover the bud.
Buds with such coverings are called *scaly buds*.
2. Pick off the scales one by one, beginning with the lowest, until well-developed leaves are reached, arrange them, in order, in a row, and notice :—
3. That the inner scales are less brown, larger, and more of a greenish color.

4. That the innermost have small structures at their tips, shaped something like the blades of ordinary leaves.
5. Draw the series.
6. From this series we learn that the bud scales really represent altered leaves, are, as we say, *homologous with leaves*; and not only this, but they are really *flattened petioles*. *Scale homologous with petiole*

VII. Examine the scales of opening buds of the Lilac or of a Pittosporum in the same way.

1. With what part of the leaf are these bud scales homologous? *the blade*
2. Make a sketch of the series.

VIII. Examine the scales in opening buds of the Tulip Tree, the Fig, the Beech, or the Hazel. Notice:—

1. That they are in pairs at the base of each petiole.
2. With what part of the leaf are these scales homologous?
3. Make a sketch of the series. *stipule*

IX. Examine the terminal buds of the Walnut, Butternut, or Witch Hazel. Notice:—

1. The absence of scales.
2. These buds are called *naked buds*.
3. Make a sketch.

X. Examine several terminal and lateral buds of the Buckeye, Maple, or Lilac, cutting them into halves, longitudinally. Notice:—

1. That some of them contain leaves only. They are *leaf buds*.
2. That some contain both leaves and flowers. They are *mixed buds*.

3. That some contain flowers only. They are *flower buds*.
4. Make sketches of the cut surfaces in each case.

XI. The buds which we have been studying, have all been *winter buds*, formed towards the end of the season of growth and then resting before expanding to furnish the shoots of the next season. But we may find buds at the end of any stem or branch which is actively growing.

Examine the end of a branch of some actively growing plant, such as a Sunflower, a Fuchsia, a Bean, or a Pea, and notice : —

1. The smaller or larger bunch of leaves, more or less closely folded together. This is a *vegetative bud*.
2. Watch this or any winter bud as it unfolds and notice : —
3. The lengthening internodes separating the leaves from one another.
4. The unfolding and expanding of the leaves.

XII. The buds which we have been studying thus far have all been regularly placed either at the top of the stem or upon the sides, in or near the axil of a leaf.

Sometimes buds appear upon the internodes of the stem, upon the roots, or even upon the leaves. Such buds appearing out of the ordinary positions are called *adventitious buds*.

1. Examine the buds which appear upon a Sweet Potato (a root) which has been kept partly immersed in water for two or three weeks. They are adventitious buds. Sketch.
2. Examine the buds which appear in the indentations of a leaf of *Bryophyllum* (a not uncommon greenhouse plant) which has been cut off and pinned up against the wall for a week or two. They are adventitious buds. Sketch.

3. Adventitious buds appear upon the older stems of many plants after they have been injured.

XIII. Examine the plumule of a well-soaked Bean. It is *the first bud*.

XIV. Classification of Buds.

POSITION.		COVERINGS.	CONTENTS.
{	Terminal.	scaly.	leaf.
	Lateral.	naked.	flower.
{	Adventitious.	{	mixed.
	axillary.		
	accessory.	{ superposed.	
		{ collateral.	

XV. Questions about Buds.

1. What is a bud?
2. What is the difference between an ordinary vegetative bud and a winter bud?
3. How do we classify buds as regards their positions on the stem?
4. As regards their coverings?
5. As regards their contents?
6. What are bud-scales homologous with? Explain several cases.
7. What do buds develop into?
8. How may we tell this year, how many buds (and branches if they all develop) will be provided for next year?
9. What is the axil of a leaf?
10. How may we tell a branch-structure from a leaf-structure by attending to its position in connection with the axil?
11. What are adventitious buds?
12. Where may they occur?
13. What is the purpose of the accessory buds in the Butternut? In the Maple?

CHAPTER IX

PRÆFOLIATION

I. **Præfoliation** (called also *vernation*) refers to the manner in which different leaves are packed away in the bud. We may regard the scaly winter bud as a sort of trunk full of foliage with which the branch or stem is to be clothed next season. The ordinary vegetative and naked buds are merely bundles of clothing. As is the case with garments put away for future use, each leaf must be packed in with the others so as to occupy as little space as possible. Consequently each leaf is, in most cases, carefully folded or rolled up in some particular way. A short study of the different ways adopted by different plants is very instructive. The botanist has a special term to indicate each particular method.

II. Examine the terminal bud of the Lilac (one which is just unfolding will be best suited for the purpose). Remove the bud-scales and notice : —

1. That the leaves are not folded, but lie flat, one against another.
2. The small size of these young leaves as compared with an adult leaf.
3. Cut across the middle of such a bud and examine the cut surface with a lens. Make a sketch, showing the way in which the leaves fit together.
4. These leaves are simply *plane*.

III. Examine a large opening bud of a Maple or Currant, and after removing the bud-scales notice : —

1. The short petioles of the young leaves.
2. The blades folded together so as to make several longitudinal *plaits* or *folds*.
3. Cut across the middle of a bud, examine the cut surface with a lens, and make a sketch, showing
4. The relative positions of the folded leaf-blades and
5. The method of folding in each case.
6. Such præfoliation as this, is called *plicate* or *plaited*.

IV. Examine a terminal opening bud of a Magnolia and after removing the bud-scales, notice : —

1. The young leaves, folded together along the midrib, bringing the inner surfaces together.
2. Cut across the middle of a bud, examine the cut surface with a lens, and make a sketch, showing
3. The relative arrangement of the folded leaf-blades and
4. The method of folding in each case.
5. Such præfoliation as this, is called *conduplicate*.

V. Examine the opening buds of the Tulip Tree in the same way and notice : —

1. The conduplicate blades.
2. That the blades are also bent forward upon the petioles.
3. Make a sketch of a single leaf to show these points.
4. The leaves of the bud of the Tulip Tree, then, show not only *conduplicate* but also *reclinate præfoliation*.

VI. Examine a large opening bud of the Cherry or of the Japanese Quince, and after removing the bud-scales; notice : —

1. That each leaf-blade is rolled up, beginning at one margin.
2. Cut across the middle of a bud, examine the cut surface with a lens and make a sketch, showing
3. The relative arrangement of the folded leaf-blades and
4. The method of folding in each case.
5. The præfoliation of the leaves just studied is said to be *convolute*. (This is also well shown by the opening leaves of the Calla.)

VII. Examine the opening leaves of the Violet and notice :—

1. That each margin of the leaf is rolled inward until the two rolls thus formed meet at the central line.
2. Cut a leaf across the middle, examine the cut surface with the lens, and make a sketch.
3. This is called *involute præfoliation*.

VIII. Examine the opening leaves of an Azalea or of a Dock (the species with large leaves are the best) and notice :—

1. That each margin of the leaf is rolled backward until the two rolls thus formed meet in the middle line.
2. Cut across the middle of a leaf, examine the cut surface with a lens, and make a sketch.
3. This is called *revolute præfoliation*.

IX. Examine the opening leaf of a Fern and notice :—

1. That the apex of the leaf is curved downwards and inwards and that a scroll is thus formed, looking like a crozier.
2. Make a sketch from the side.
3. This is called *circinate præfoliation*.

X. Questions upon Præfoliation.

1. What is præfoliation?
2. Why should there be different kinds of præfoliation?
3. What kinds of præfoliation are there?
4. Which part of the leaf is generally concerned in præfoliation?

CHAPTER X

PROTECTION

THE plant finds itself exposed to numerous enemies, and many peculiarities of habit and structure assist directly in protecting the plant against them. For the present we need consider only the ways in which the plants protect themselves against the attacks of those animals which eat its substance, either grazing animals, or insects and their larvæ, such as caterpillars and the like. We are to notice not only the particular means employed, but also which of the three primitive organs (*i.e.* root, stem, or leaf) of the plants is modified, in each case, to provide the means.

I. Examine a branch of the Orange or Thorn and notice :—

1. The stout thorns, and
2. The relation of each to the adjacent leaf (or leaf-scar if the leaves are not present).
3. Make a sketch of a portion of the branch with one thorn and its adjacent leaf.
4. Do these thorns represent stem-, leaf-, or root-structures?
5. Write down your answer and the reasons for it.

II. Examine a branch of the Barberry, the Gooseberry, or the Currant, and notice :—

1. The weak spines, and
2. The relation of each to the adjacent leaf or bud.

3. Make a sketch to show this.
4. Do these spines represent stem-, leaf-, or root-structures?
5. Write down your answer and the reasons for it.

III. Examine a branch of the Locust Tree or of the Spiny Acacia and notice : —

1. The pairs of spines and
2. The relation of each to the adjacent leaf (or leaf-scars if the leaves are not present).
3. Make a sketch to illustrate this.
4. Do these spines represent stem-, leaf-, or root-structures?
5. Can you state even more exactly just what particular structures they represent?
6. Write down your answers, and the reasons for them.

IV. Examine branches of the Rose or of Brambles (Blackberry, Raspberry, Thimbleberry, etc.) and notice : —

1. The prickles, and
2. Their relations to the leaves (or leaf-scars).
3. Make a sketch to represent this.
4. Cut one into two halves longitudinally, and make a sketch.
5. Do these prickles represent stem-, leaf-, or root-structures?
6. Write down your answer, and give your reasons for it.

V. Examine a leaf of the Thistle and notice : —

1. The numerous sharp spines upon each leaf.
2. Make a sketch of this leaf.
3. What other leaves can you think of, that are protected in the same way? Write down the list.

VI. Examine the leaves and stems of some Buttercups, Wormwood, Mayweed, or Eschscholtzia, and notice : —

1. That there are no thorns, spines, or prickles to protect the plant.
2. Bite into a leaf or stem, and taste the juice. Describe the taste.
3. Offer, at some time when you can, some of these plants to a cow, and make notes of her actions.
4. Observe whether cattle readily eat these plants in the pastures, or whether they leave them untouched.

VII. Mention any plants found in your vicinity which have poisonous juices, *i.e.* either to the touch or when eaten by men or by cattle.

VIII. Examine the leaves and stems of the common Nettle and describe how this plant protects itself.

IX. Examine the very woolly leaves of the Common Mullein. Cut it across and notice :—

1. The thick covering of white hairs on each surface.
Examine with the lens.
2. Make a sketch of one of the cut surfaces to show this.
3. How may this protect the leaf against insects or even grazing animals.

X. Mention and describe many other ways in which plants protect their foliage and tender stems from being eaten ; such as, by placing it above their reach (consider the giraffe as an animal especially adapted to feed on such plants), or by growing too close to the ground, etc.

XI. (a) Do plants need to protect themselves against any other enemies than grazing animals? If so, from what? and how?

(b) Sum up, briefly, the different ways by which plants protect their foliage and stems from being eaten.

CHAPTER XI

STORAGE

MANY plants arise from the seed, develop stem, leaves, flowers, and seeds, and die within the same twelve months in which they began their life. Such are the common plants which we call annuals. Other plants live on from year to year and produce successive crops of flowers and seeds. Such are the plants called biennials and perennials. Plants living merely for a single year provide only for their offspring in maturing suitable seeds, but plants which live for more than one year store away reserve materials which are used for the growth of the succeeding year or years. In this way plants living on indefinitely are using this year the materials which they stored up last year, and are storing up materials for use next year.

The parts of the plant in which the materials are stored are usually very noticeably thickened. If we examine thin sections of these parts under the lenses of a compound microscope and apply the proper tests, we shall find that these storehouses of the plant contain starch, sugar, oils, and various albuminous substances.

I. Take a Cactus and examine, noticing : —

1. The much thickened stem and
2. The leaves, reduced to small spines.
3. Make a sketch of the plant showing these features.

4. In what sorts of countries or in what sorts of places do Cacti grow?
5. How does this explain the much thickened stem and lack of leaves?
6. Of what use are the spines to the Cactus?

II. Take a plant of the Agave or Century Plant and notice :—

1. The short stem.
2. The stout thickened leaves.
3. Make a sketch of this plant.
4. How often does the Century Plant blossom?
5. What happens to the plant after blossoming? *die*
6. Find out whatever you can about the Pulque, manufactured by the Mexicans from the juice of the Agave.
7. In what sorts of countries are Agaves found?
8. Loosen the epidermis of one of the leaves with a knife and peel off a piece. Notice its thickness and firmness. What is the reason for this?
9. How does the Agave protect itself against grazing animals? Why should this be necessary? *to preserve its store of nourishment*

III. Examine a plant of Iris which has been removed carefully from the soil in which it was growing. Notice :—

1. The thickened, horizontal, underground portion and
2. The transverse scars. What caused them?
3. Is this thickened portion, root, stem, or leaf?
4. Write down your answer and give your reasons for it.
5. Make a sketch of the Iris. *Jerusalem Artichoke*

IV. Take a Potato and examine it, noticing :—

1. Its general size, shape, and color.
2. Does the Potato grow above or below ground?

3. What sort of plant-structures are the "eyes" of the Potato? Why?
4. At what point was the Potato attached to the rest of the plant?
5. Make a sketch of the Potato.
6. Is the Potato stem, root, or leaf? *Stem*
7. Write down your answer and give your reasons for it.
8. The Potato is a good example of a *tuber*. Write down the best definition for a tuber which you can find.

V. Examine the *corm* or *solid bulb* of a *Gladiolus* or *Brodiaea* and notice :—

1. The general shape, size, and color.
2. The roots (or remains of them) from the lower surface.
3. The buds (or leaves and flowers) from the upper surface.
4. Make a sketch of one corm.
5. Is the corm situated above or below the surface of the ground during the life of the plant?

VI. Cut the corm into two longitudinal halves. Examine one of the cut surfaces and notice :—

1. The thin outer skin, separate from
2. The solid inner portion.
3. The buds (or leaves and flower stems) at the upper portion.
4. The roots coming off from the upper portion.
5. Make a sketch of one of the cut surfaces and label carefully the different parts.
6. Is the corm stem, root, or leaf?
7. Write down your answer and the reasons for it.

VII. Take a bulb of some *Lily* and examine it, noticing :—

1. The general shape, size, and color.

2. The roots, all from the lower end.
3. The thick, pointed, fleshy scales which make up the greater part of the bulb.
4. Make a sketch of the Lily-bulb as seen from one side.
5. Is the bulb of the Lily situated above or below the ground during the life of the plant?

VIII. Cut the bulb of a Lily into two longitudinal halves. Examine a cut surface and notice : —

1. The small solid piece at the base from which the roots are given off. Is this root, stem, or leaf?
2. The cut surfaces of the separate scales.
3. The bud (or leaves and stem) at the top of (1).
4. What plant-parts do the scales represent?
5. Make a sketch of the cut surface to show these parts.
6. What plant-parts, then, does the Lily-bulb represent?
7. The Lily-bulb represents what are called *scaly bulbs*.

IX. Examine the bulb of a Hyacinth or an Onion. Notice : —

1. The general shape, size, and color.
2. The roots from the lower side.
3. Make a sketch of this bulb.
4. Is the bulb of the Hyacinth or the Onion situated above or below the ground during the life of the plant?

X. Cut the Hyacinth or the Onion into two longitudinal halves. Examine one of the cut surfaces carefully and notice : —

1. The small solid piece at the base from which the roots arise.
2. Is this stem, root, or leaf?
3. The narrow, curved layers which make up the greater part of the substance.

4. What do these layers represent?
5. The bud or young leaves at the very centre.
6. Make a sketch of one of the cut surfaces.

XI. Cut a bulb of the Hyacinth or the Onion across the middle. Examine one of the cut surfaces and notice : —

1. The concentric arrangement of the coats and
2. How closely they are applied one to the other.
3. The Hyacinth and Onion represent what are called *tunicated bulbs*.

XII. 1. How may we distinguish between a *corm* and a *bulb*?

2. Write down the best definition you can find for each.
3. How may we distinguish between *tunicated* and *scaly bulbs*?
4. Examine the so-called bulbs of the Tuberose, the Tulip, the Star-of-Bethlehem, the Soap-Root, the Dog-tooth Violet, and any others obtainable, and name each correctly.

XIII. Take a Radish, Carrot, or Beet, examine the underground portion carefully, and notice : —

1. The size, shape, and color.
2. Any markings upon the surface.
3. Make a sketch.
4. Is the part studied root, stem, or leaf?
5. Write down your answer and give your reasons for it.
6. How long does the Carrot, Radish, or Beet live?

XIV. How is nourishment stored up in the seed for the use of the embryo?

XV. If thin slices of the wood of the trunk, branches, and roots of trees be examined under the compound microscope during the resting season (winter) and tested with the proper chemicals, it will be found that considerable quantities of starch are stored away in the pith, medullary rays, and even in the wood cells for use during the season of rapid growth.

XVI. Of what advantage to the plant are the supplies of nourishment thus stored away?

XVII. Write a summary of this chapter, stating what plant-parts are used for the purpose of storing food materials, and how they are modified to do so.

CHAPTER XII

CLIMBING PLANTS

IN our work upon stems (compare Chapter IV), we found that one of the functions or uses of the stem was to support the leaves and to carry them up into the air.

When we examine plants as regards height of stem, we find that this varies from almost nothing to several hundred feet. We find also, as a general rule, that the higher the plant rises into the air, the stouter the stem becomes, until we have such stems as the trunks of trees.

There is one set of plants, however, which do not follow this rule. They rise above their neighbors to obtain the air and sunshine they covet, while still possessing weak and slender stems. Such are the plants which have climbing habits.

I. Take a plant (or the upper portion of a plant) of the Hop or of *Manettia*. Examine it carefully and notice:—

1. The very slender stem.
2. That it has entwined itself spirally about a *slender* support.
3. That it twines about the support *with the sun* or from *right to left* (as one faces it).
4. The tip, usually extending out at nearly right angles to the support, and then curving abruptly.
5. Make a sketch to show these points.

6. If the Hop is used, examine the surface of the stem to see how it manages to obtain a firmer hold upon the support.

II. Take a plant (or the upper part of a plant) of the Morning Glory. Examine it carefully and notice :—

1. That it is very similar to the Hop, except
2. That it twines around its support in exactly the opposite direction, *i.e.* directly *against the sun*, or from *left to right*.
3. Make a sketch to show this.

III. 1. Watch both plants for several days, and notice how they twine about the support.

2. Try to make each twine in the opposite direction by twisting it about its support in the opposite way and tying it. Notice :—
3. That as soon as the tip grows out beyond where it has been tied, it returns to its former way of twining.

IV. Examine all the twining plants you can, and compare them with those you have studied.

V. Examine a plant of the common Squash and notice :—

1. The slender weak stem.
2. The tendrils ; slender lateral prolongations which curve at the tips and coil about slender objects with which they come into contact.
3. That the tendrils contract spirally (*i.e.* shorten themselves by coiling), and
4. That, at the end next the stem, they coil in one direction, while at the end nearest the support, they coil in the opposite direction.

5. Notice also the relation, as regards position, existing between each tendril and the adjacent leaf.
6. Make a sketch to show these points.
7. Is the tendril a stem, root, or leaf ?
8. Write down your answer, and give your reasons for it.
9. How, then, does the Squash raise itself into the air and sustain itself there ?

VI. Examine a Pea Plant and notice the tendrils.

1. How do they differ from those of the Squash ?
2. Are they stems, roots, or leaves ?
3. Sketch the tendril of the Pea and the adjacent structures to show these parts.

VII. Examine tendrils in as many different plants as you can, and compare them with those you have studied.

VIII. Examine a plant of the Jasmine-flowered Nightshade (*Solanum Jasminoides*) and notice : —

1. That its tip twines about the support. In what direction ?
2. That the petioles of the leaves clasp the stem tightly, and become much thickened.
3. Make a sketch to show this.

IX. Examine a plant of Clematis or Virgin's Bower and notice : —

1. The twining habit and its direction.
2. The compound leaves, clasping the support both by means of the main petiole and by means of the petioles of the leaflets.
3. Make sketches to show this.

X. Examine the English Ivy and notice : —

1. That the stem does not twine.

2. That the stem fastens itself to large objects by means of numerous small rootlets (*aërial rootlets*).
3. Make a sketch to show these points.

XI. Do you know of any other plants which climb as the English Ivy does?

XII. Write out a short essay upon the different methods in which plants climb, explain the advantages of each, and show what different parts of the plant are modified to form climbing organs.

CHAPTER XIII

EPIPHYTES, PARASITES, AND SAPROPHYTES

WE have, thus far, been studying plants with roots spread out under ground and obtaining food for the plant from the earth. These plants have also been in the possession of *green* leaves, well developed, acting as foliage, to obtain materials from the air for the use of the plant and working over the materials thus obtained by themselves and by the roots, and manufacturing from them the substances needed by the plant for its own processes of life.

Since we are about to study several plants which live in different ways from the ordinary plants, we shall find it to our advantage to remember that the ordinary or *typical* plant behaves as follows : —

1. It buries its roots under the surface of the earth in order that it may obtain water and whatever is dissolved in it.
2. It spreads out its leaves into the air to expose them to the air and the sunlight.
3. Its leaves are green as long as they are healthy, but turn yellow as they begin to die or are deprived of sunlight.

I. Take one of the Orchids of the greenhouses which are grown on hanging pieces of wood. Notice : —

1. That the roots hang down into the air and do not seem to need to penetrate the earth.
2. That the air of the greenhouse is damp and warm.
3. That the leaves are expanded and green.
4. Make a sketch of the Orchid to show these points.
5. This is an *epiphyte*, or a plant which grows upon another plant and yet does not draw any nourishment from it.
6. The roots are called *aërial roots*, and obtain nourishment from the damp air. *The most conspicuous epiphytes are found growing in the tropical zone.*

II. Take a Lichen, such as are common upon the bark of trees. Notice :—

1. That it simply grows upon the surface.
2. It is a good example of an epiphyte, but it belongs to an entirely different class of plants from those we have been studying. It has no distinct stem and leaves, no flowers, no real roots, etc. (It belongs to those plants which we call *flowerless* plants, while we are studying the *flowering* plants chiefly.)

III. Take a piece of Mistletoe, together with a portion of the branch to which it is attached. Notice :—

1. The distinct stem.
2. The *expanded, green* leaves.
3. The close union with the *host* (*i.e.* with the tree or shrub upon which it is growing).
4. Make a sketch to show these characteristics.

IV. Cut through the base of the Mistletoe and the branch of its host at the point of union (longitudinally as regards the mistletoe). Notice :—

1. The extension of the Mistletoe under the bark of the host.

2. The close contact between this extension and the wood of the host.
3. The *suckers* or projections from the extension into the wood of the host. (These are found only in the European Mistletoe (*Viscum album*).
4. Make a sketch to show these points.

V. The Mistletoe, then, not only grows upon another plant, but it sends its roots (viz. the "extensions") down into the substance of that plant to draw away its sap instead of hanging them out into the air as the Orchid does. The Mistletoe is a *parasite*, living at the expense of another plant.

It is also a *green parasite*, and takes only crude sap (*i.e.* the sap passing up from the roots to the leaves) from its host, but it still possesses green leaves like other plants to take materials from the air and to work over or elaborate the materials obtained in these two ways for its own benefit.

VI. Take a piece of the Dodder together with a portion of the host plant around which it is entwined. Notice:—

1. The slender twining stem *destitute of leaves*.
2. The direction in which it twines about the stem of the host plant. (Compare Chapter XII, §§ I and II.)
3. The absence of a root at the lower end. (For the purpose of demonstrating this point, it will be necessary to examine young plants where they grow.)
4. The small *suckers*, arising from the stem and penetrating the host plant.
5. The color of the stem and suckers.
6. The flowers, if any are present.
7. Make a sketch to show these points.
8. Are the suckers root-, stem-, or leaf-structures?
9. Why does the Dodder lack leaves of any appreciable size?

10. Write down your answers and give your reasons for them.

VII. In the case of the Dodder, we have a parasite which is not green, *i.e.* a *pale parasite*.

VIII. Place a piece of stale bread in a soup plate, wet it thoroughly, cover with a bell-glass or cake-jar, keep in a warm place for a week (or even two weeks), and then examine. Notice :—

1. The cobwebby grayish mass that has grown upon the bread.
2. This is the "Bread-Mould." It is made up of
3. Fine threads, the *hyphæ*, and
4. Small black globes, the *sporangia*.
5. On examining the latter under the dissecting microscope, we shall find a mass of small blackish bodies, the *spores*. Spores differ from seeds, especially in having no embryo within the spore-coats; but we shall study a little more about spores later on. We are now interested in the way in which the Bread-Mould obtains its food. Notice :—
6. The absence of a green color.
7. The small rooting organs which attach the Mould to the bread.
8. This is an example of a class of plants called *saprophytes*, which live upon dead organic matter (in the case of the Mould, represented by the bread).

IX. Does the bud or scion, grafted upon a stock in the orchard, resemble a parasite? If so, in what way? Write your answers and give your reasons for them.

X. Write out a set of comparisons, stating resemblances and differences between the following sets : —

1. The typical green plants and the green parasites.
2. The green parasites and the pale parasites.
3. The pale parasites and the saprophytes.

XI. Show how a typical plant might be led to become a saprophyte and what changes would take place. Write out your opinions on these points in the form of an essay, stating facts supporting them.

CHAPTER XIV

INSECTIVOROUS PLANTS

WE have seen in the preceding chapter how some plants, departing from the simple habits of the ordinary *green* plant, obtain their nourishment from other plants or even from dead organic matter. There are still several of the larger and more complex plants which capture and digest (to some extent at least) small animals, such as insects, water-fleas, etc., and are provided with special apparatus for the purpose. We call them Carnivorous or Insectivorous Plants.

I. Examine the leaf of the Common Pitcher Plant (*Sarracenia purpurea*), and notice : —

1. The hollow, pitcher-shaped *petiole*.
2. The small *blade*, forming the lip of the pitcher.
3. The contents, both liquid and solid.
4. The inner surface of the blade, *i.e.* the hairs clothing it, the direction in which they point, etc.,
5. That they stop abruptly at the lower limit of the blade, and that the surface of the inside of the pitcher is perfectly smooth.
6. How does this arrangement of hairs and smooth surface help to entrap an insect? Where would it alight and what would happen to it? Write out the story of its capture.
7. Make sketches of the whole leaf and of its parts.

II. Examine a leaf of the Californian *Darlingtonia* and notice : —

1. The general shape, size, color, etc.
2. The parts —
 - (a) lower slender portion and
 - (b) upper hood-shaped portion of the *petiole* ;
 - (c) the split *blade* hanging out “mustache fashion” beyond
 - (d) the elliptical opening with its incurved rim.
3. Make sketches to show these parts and label.

III. Cut a leaf open and notice : —

1. The *transparent spots* (“*windows*”) and
2. The downwardly projecting hairs within the hood.
3. The smooth inner walls of the slender tube.
4. The contents, solid and liquid, of the lower part of the tube.
5. Write out the story of the trapping of an insect by this leaf.

Where does it alight?

What is the rim of the opening for?

What are the hairs for?

Why do they point the way they do?

What are the windows for?

What is the smooth surface for?

What is the liquid for?

Is this liquid produced by the plant or not? Give the reasons for your answers.

IV. Examine the leaves of a healthy plant of the Venus Fly-trap, and notice : —

1. The *petiole*, flattened, with a longitudinal groove through the middle.

2. The contraction just under the
3. Blade which consists of two parts.
4. The teeth upon the margins of the blade.
5. The bristles upon the upper surface of the leaf-blade.
6. Notice especially this upper surface of the blade.
7. Make sketches to show these points.

V. Irritate the blade by touching the bristles upon the upper surface and notice the details of its movements. Describe them. How long does it take to close? Does it open again?

VI. Place a small piece of meat upon the upper surface of the lamina. Watch and take notes for several days.

VII. Examine an expanded (*i.e.* open) leaf of the Common Sundew and notice:—

1. The slender petiole.
2. The thick rounded blade with
3. The projecting *glands* upon their stalks, covering the upper surface.
4. Make sketches to show these characters.

VIII. Place a small piece of meat upon the centre of the upper surface of an expanded leaf, and notice what happens. What parts move first? next? next? and so on. Keep watching the plant as you have opportunity for several days.

IX. What is the difference as regards the method of capturing the prey between the two Pitcher Plants on the one hand, and the Venus Fly-trap and the Sundew on the other? Write your answer.

X. Are the Insectivorous Plants parasites or saprophytes? Why?

CHAPTER XV

REPRODUCTION

A SINGLE plant is an *individual*. Any method, by which the number of individuals of a species is increased, is called a *method of reproduction*.

A plant may produce new individuals, *i.e.* increase the number of independent plants, by simply splitting or dividing itself up, by detaching parts of itself, or it may produce special bodies which are unlike any of its ordinary vegetative parts, and these bodies finally produce new plants. Accordingly, we may distinguish the two general methods of reproduction, as follows :—

I. Vegetative Reproduction.

II. Seed and Spore Reproduction.

CHAPTER XVI

VEGETATIVE REPRODUCTION

VEGETATIVE REPRODUCTION, in its broadest meaning, includes all those methods of increasing the number of the individuals of a species other than by the special bodies called seeds and spores. Some plants have a number of ways of multiplying vegetatively, others very few or none at all. We shall examine a few typical cases.

I. Take a well-grown stem of the Tiger Lily of the gardens and notice :—

1. The stem.
2. The leaves.
3. The black bodies in the axils of the leaves. They are called *bulblets*.
4. Sketch a piece of stem, a leaf, and a bulblet.
5. Are the bulblets leaf- or branch-structures? Write down your answer and give reasons for it.

II. Detach a bulblet, dissect it and make sketches.

1. Do the bulblets drop off or not?
2. What is the bulblet for?
3. How does it produce a new individual?

III. Examine the flowering portions of a number of cultivated Onions and notice :—

1. That some of the flowers have been replaced by bulblets.
2. Make a sketch to show this.

IV. Examine the axils of the leaves of a Yam (if opportunity presents) and notice the small tuber-like bodies (resembling small Potatoes) found there.

V. Examine the underground portion of an old Raspberry Plant and notice : —

1. That branches are given off from the main plant below the ground, which run along for a short distance, then turn upward and produce a new shoot which makes its way into the air.
2. Make a diagram of this.
3. Such a branch is called a *sucker*.
4. How does the gardener take advantage of suckers to obtain new Raspberry Plants?

VI. Examine a group of Strawberry Plants and notice : —

1. One of the slender, tendril-like branches sent out from the main plant.
2. That it curves over so that the tip may rest upon the ground.
3. That roots, springing from the tip, penetrate the ground ; that leaves are produced ; and that finally there is a young plant attached to the parent plant by a slender piece of stem.
4. That finally this stem dies and the young plants are free.
5. Make diagrams to show these points.
6. Such a slender branch, behaving in this way, is called a *runner*.

VII. Plants having underground stems which branch, increase in number by the dying away of the older portions of the stem. When the dying portion reaches a place where a branch is situated, the union between the two parts is broken and instead of one plant we have two. After this has been repeated several times, there are several plants, all from the same original stock.

To realize how this may happen, examine the slender root-stock of some Mint or Grass and notice :—

1. The branches, which may be numerous or may be few.
2. The nodes and internodes.
3. The buds at the nodes, which may develop into lateral branches.
4. The terminal buds at the ends of the branches.
5. How the root-stock is dying away at the other end of the root-stock.
6. Make sketches to show these points.

VIII. Examine the underground portions of Iris, notice how it is multiplied (as described in VII) and make diagrams to show it.

IX. Examine slips or cuttings of Pelargoniums, English Ivies, or Willows, which have been planted in moist sand for several weeks. Make sketches and describe what has happened. What are the advantages of propagating a plant by cuttings over propagating by seed? Write your answers.

X. Examine leaves of *Bryophyllum* (or leaf-cuttings of some species of "tuberous Begonia") which have been lying upon moist sand. Notice and sketch the buds formed at the notches in the margin of the leaf (or at the cut ends of the ribs of the leaf of the Begonia)—sketch and label.

XI. Explain how grafting and budding enable man to propagate a particular form and why he resorts to this method.

XII. Examine the stem of the Prickly Pear Cactus (*Opuntia*), and notice the *joints* of which it is made up. Each joint may separate, or be separated, and grow into a new plant. Make notes and sketches.

XIII. Do you know of any plants other than those just studied which multiply vegetatively? If so, name and describe them.

XIV. Compare the different methods of vegetative reproduction which you have studied, stating particularly whether root-, stem-, or leaf-structures were employed.

CHAPTER XVII

SEED REPRODUCTION

IN our earliest work we examined carefully a number of different seeds and learned that *a seed must contain an embryo* or rudimentary plantlet—showing, usually, distinct stem- and leaf-portions, with a provision, also, for the production of a root or roots.

We know, also, that *flowers precede fruits* and that the *fruits contain seeds*, in the ordinary plants. Consequently we shall first consider various kinds of flowers as well as matters pertaining to them and then fruits, in order to study the important details of reproduction by seeds and the phenomena attending it.

flower is a modified branch with
 reduced internodes and leaves changed
 size shape & color for the function of
 reproduction

CHAPTER XVIII

A TYPICAL OR PATTERN FLOWER

Red flower

I. Take a flower of some species of *Crassula* and notice :—

1. Its size, shape, color, etc.
2. Its structure :—
 - (a) A circle of green, leaf-like pieces on the very outside. These are called *sepals* and the circle of sepals is called a *calyx*.
 - (b) How many sepals are there?
 - (c) Are they all alike?
 - (d) Next to these a circle of colored parts, the *corolla*, composed of *petals*. How many petals are there? Are they all alike?
 - (e) Following the petals, a circle of *stamens*. How many are there? Are they all alike?
 - (f) Each stamen is made up of two parts, the *stalk* or *filament* below and the *anther* or sack containing the yellow dust (*pollen*) above.
 - (g) The innermost circle of green bodies, the *pistils*, each of which is composed of three parts :— the lower swollen portion, the *ovary*; the slender portion above it, the *style*; and the small body at the tip, the *stigma*.
 - (h) How many pistils are there? Are they all alike?

II. Remove several stamens entire, examine one a little more carefully under the lens and notice : —

1. The size, shape, and color of the filaments.
2. The way in which the anther is attached to the filament.
3. Examining the anthers in some buds or flowers not yet opened, notice the two longitudinal halves of each anther — each is called an *anther cell*.
4. Examining the stamen of an older flower, notice how each anther cell opens to allow the pollen to escape.
5. Make sketches to show this.

III. Remove several pistils carefully and examine the different parts under the lens (or better, under a dissecting microscope). Notice : —

1. The stigma, its size, shape, and structure. (Compare if possible the stigma of the pistil of a Lily or Begonia and notice the roughness and moistness of the stigma. Touch such a stigma to the tongue and notice its taste. Sometimes the stigma of the Lily has enough moisture upon it to form a distinct drop.)
2. The slender style, its smoothness as compared with the stigma.
3. The swollen ovary. Carefully cut the ovary longitudinally along one edge and open it. Within will be found
4. A hollow, the *cell* of the ovary — within the cell may be seen
5. A row of small bodies, the *ovules*. These are the bodies which ripen into seeds.
6. The surface to which the ovules are attached is called the *placenta*. This pistil has only one placenta.
7. Make a sketch (or diagram) to show these points, and label carefully.

IV. Such a pistil is called a simple pistil because it has only one stigma, one style, one ovary, one cell to the ovary, and one placenta. (Any pistil having more than one style stigma, ovary-cell, or placenta, is called a *compound pistil*. Compound pistils are more common than simple ones.)

V. Pick off all the parts of the flower in regular order, beginning with the sepals. The small conical tip of the stem upon which they are inserted is called the *receptacle*.

VI. This flower is an example of a *perfect, complete, regular, and symmetrical* flower.

1. It is *perfect* because it has both stamens and pistils.
2. It is *complete* because it has all the organs possible for a flower to have : viz. sepals, petals, stamens, and pistils. (A complete flower must necessarily be perfect.)
3. It is *regular* because in *each* circle *all* the parts are of the same *size* and *shape* (*i.e.* without any striking differences).
4. It is *symmetrical* because each circle contains the *same number* of parts as *each other* circle.

VII. **Alternation of the Parts of the Flower.** — Take an uninjured flower and notice : —

1. Whether the petals are in front of the sepals or in front of the spaces between the sepals.
2. Does the same thing hold true for the stamens in relation to the petals?
3. For the pistils in relation to the stamens?
4. This is called the *alternation of the parts of the flower* and is true for the parts of most flowers.

VIII. **Ground Plan of the Flower.** — Draw by the aid of a pair of compasses four faint concentric circles, one within the other.

1. Upon the innermost, represent the five pistils (drawing cross-sections of the ovaries).
2. In the next outer circle, represent the stamens (by cross-sections of the anthers) alternating with the pistils.
3. In the next outer circle, represent the petals (by cross-sections) alternating with the stamens, and finally
4. Represent the sepals in the same way in the outermost circle.
5. This is what is usually called a *ground plan of the flower* and represents the *number* and *alternation* (or lack of it) of the parts in such a way that they may be seen at a glance. To be especially accurate, the particular way, which varies somewhat in different flowers, in which the sepals or petals overlap one another, should also be represented.

IX. **The Numerical Plan of the Flower.** — The numerical plan of a flower is represented by the number which predominates in the different circles of the flower. In the flower just studied the same number is represented in each of the four circles. What is its numerical plan?

X. The *Crassula* is a *type* or *pattern flower* because it is complete, regular, and symmetrical, has alternation of parts, and all the parts free and distinct one from the other. A flower must have these five qualities to be a pattern flower. Few flowers are pattern flowers.

XI. *A flower must contain either pistils or stamens (or both).* Some flowers are reduced to a single stamen or a

single pistil, but such flowers are neither common nor conspicuous. The stamens and pistils are therefore called the *essential parts*.

XII. Carefully review the terms given in this chapter and become thoroughly acquainted with the definition of each.

CHAPTER XIX

FERTILIZATION

WE all know that the fruit and seed follow the flower, and as we go on to study the flower further, we see that everything about it is constructed to favor the development of the seed. Color, fragrance, position on the plant, time of opening and shutting, the massing of flowers together ; in short, every detail of structure to be found in any flower, is to help in this work.

We found in the ovary-cell certain ovules, which develop into seeds under proper conditions. Let us consider one of the most essential conditions to the development of the seed from such ovules.

Within the ovule there is no embryo at first, but there is, among other things, a very small body, visible only under the higher powers of the compound microscope, called the *nucleus*. Within each little particle or grain of pollen there is another microscopic *nucleus*. These two nuclei must come together in the body of the ovule and unite into one before the processes which result in the growth of an embryo may be started. The process of accomplishing this is called *the fertilization of the flower*.

But in order that the nucleus from the pollen grain may unite with that in the ovule, it must get over from the anther, in some way, and down to the ovule itself ; for the ovule remains stationary, while the pollen grain is free to be

moved. Consequently, first, the pollen grain must get from its home in the anther cell to the stigma. This is the first step in fertilization, and is called *pollination*. *Pollination deals with the transfer of the pollen from the anther to the stigma.*

Then the pollen grain must "grow down" through the stigma and style into the ovary cell, and penetrate the ovule, so that the two nuclei may unite. When the pollen grain falls upon the stigma, it is caught and held there by the roughness of the stigma and by a sticky sugary fluid upon it. Under the influence of this sticky fluid, the pollen grain grows out into a tube which bores its way down into the stigma and through the style (if there is any) until it comes to the ovule. The end of the tube finds its way into the ovule [through the small opening which persists in the ripened seed and is called the micropyle (compare Chapter I, § II, 6, etc.)], the nucleus which it carries comes into contact with the nucleus in the ovule, and they unite. Fertilization is then complete, and the embryo begins to form.

This second step in fertilization is called *the descent of the pollen tube*. It is very similar in all plants, and can be studied only by the aid of the compound microscope and careful and complicated preparations. But the first step, that of *pollination*, is very different in different plants, and can be much more easily made out.

We distinguish first as to whether the pollen which acts upon the stigma of a particular flower comes from the stamens of the same flower or from those of a different flower. If the former, it is called *close-fertilization*; if the latter, *cross-fertilization*.

Cross-fertilization is more common, and we shall study that first. Of course the pollen grains, having no motion

of their own, must be carried by something from the anther of one flower to the stigma of another. *Two agencies are active in this work, the wind and insects.* Flowers which depend upon insects for cross-pollination (*i.e.* pollination resulting in cross-fertilization) must, as we can readily see, have some means of attracting them. We find that flowers do this by providing bright (or conspicuous) colors, odors, or honey. Further, the flower must be constructed so that it cannot readily be self-pollinated, and from this point of view the different shapes of flowers must be studied. We shall study some of these peculiarities under the following heads: *Irregular Flowers, Unsymmetrical Flowers, Coalescence, and Adnation, which are, in most cases, devices to aid in securing cross-pollination.*

The *wind-pollinated flowers* are less complicated in structure, have *no conspicuous color, no odor, and no honey.*

During our whole study of the flower, we must ask ourselves how the flower is fertilized, *i.e.* whether it is *cross- or self-pollinated*, whether *insect- or wind-pollinated*, and what special devices are present to *secure cross- or close-pollination* or to prevent the one or the other. These things are the keys for unlocking to us the mystery of the variety of flower structure and coloration.

CHAPTER XX

IMPERFECT, INCOMPLETE, IRREGULAR, AND
UNSYMMETRICAL FLOWERS

THE pattern flower which we have just studied was perfect, complete, regular, and symmetrical. We may now study, hastily, several flowers, to understand what is meant by the converse of these terms.

I. Imperfect Flowers. — Examine the flowers of different plants of *Begonia* and notice : —

1. That some of the flowers of the same plant are provided with stamens only and others with pistils only.
2. These flowers are consequently *imperfect*, lacking one or other of the *essential parts*; viz. stamens in one case and pistils in the other.
3. Make notes and sketches.
4. Where the two different kinds of flowers are borne on different plants, the plant is said to be *diœcious*, but if they are borne on the same plant, as in *Begonia*, it is said to be *monœcious*. (Do you know of any diœcious plant?)
5. Is close-pollination possible in a monoœcious or a diœcious plant? Write down your answer and give your reasons for it.
6. Distinguish between the two kinds of cross-pollination which are possible in monoœcious and diœcious

plants. Which is most thoroughly cross-pollination? Why?

7. The student should make a special note of the fact that imperfect flowers are constructed so as to prevent close-pollination and compel cross-pollination.
8. Is the cross-pollination in the *Begonia* effected by the agency of the wind or of insects? Why?

II. Incomplete Flowers.—An imperfect flower is necessarily also *incomplete*, since it lacks entirely one of the four circles. But a perfect flower may also be incomplete; for example, take the flower of an *Anemone*, *Hepatica*, or *Prince's Feather*, and notice:—

1. That both stamens and pistils are present.
2. That only one circle of floral leaves is present, and when only one is present, it is called the *calyx*, without regard to its coloration.

III. Irregular Flowers.—Take the flowers of a *Pea*, *Bean*, *Wistaria*, *Locust*, or some other leguminous plant, and examine the corolla carefully. Notice:—

1. The *upper broad petal* of a different shape (and perhaps of a different color) from the rest. It is called the *standard* or *banner*, and is spread out to attract the insects.
2. The *two side petals*, called the *wings*, upon which the insects alight.
3. The two *lower petals*, *cohering more or less at their tips* (but seldom really grown together), forming the *keel*, enclosing the stamens and pistil.
4. Remove these five petals, lay them down in order, and sketch each to show relative size and shape.

5. The Pea Flower is a type of irregular flower found upon the majority of the plants of the *pea family*. It is called a *papilionaceous* or *butterfly flower*.

IV. Study also, if possible, flowers of the Larkspur and the Pansy or Violet for excellent irregular flowers; notice that one or more of the petals or sepals in each is prolonged into a tube or *spur* which contains honey. What is this honey for? Are the stamens all alike? Is the flower *insect-* or *wind-pollinated*? What is the numerical plan?

V. Examine, with the aid of the teacher, the flower of some Orchid, if possible, and notice the great irregularity and the devices for compelling the insect to touch first the stigma, leaving upon it the pollen brought from the last flower visited, and then, upon backing out, to smear itself with the pollen of this flower, to carry to another.

VI. **Unsymmetrical Flowers.**—Returning to a flower with a papilionaceous corolla, notice:—

1. The calyx—how many sepals are there?
2. The corolla—how many petals are there?
3. The stamens—how many are there?
4. The pistils—how many are there? How many styles?
How many stigmas? How many cells in the ovary?
How many placentæ?
5. What is the numerical plan of this flower? Write out the reasons for your answer.

VII. Review and distinguish carefully between these variations in structure and fix in mind the significance of each.

CHAPTER XXI

COALESCENCE AND ADNATION

I. Take a flower of *Convolvulus* or Morning Glory (*Ipomœa*) and notice : —

1. That the corolla is made up of one piece.
2. That there are five points or stripes to indicate that five petals are joined together at their edges.
3. Make a sketch of this corolla.
4. Such a corolla is said to be *sympetalous*, or having the petals united.¹

II. When parts of the same circle are joined together, as in the case of the petals of the Morning Glory, it is called *coalescence*. Parts of any of the four circles may be joined.

Take the Pea Flower again, and notice : —

1. The calyx, — it is *synsepalous*. Notice the lobes indicating the sepals composing it.
2. Removing the corolla, notice that nine of the stamens are united into one piece by their filaments, the tenth remaining free.
3. Such stamens are called *diadelphous* (in two brotherhoods) — if in one piece, as in some flowers of this family, *monadelphous*, etc.

¹ When the petals are separate (or "distinct"), the corolla is said to be *choripetalous*.

III. *Coalescence* between the pistils of a flower is extremely common, giving rise to what is called a *compound pistil*, or one in which the number of styles, stigmas, cells of the ovary, or placentæ exceed one.

Take the flower of a Lily or a Hyacinth and notice : —

1. The number of stigmas.
2. The number of styles.
3. Cut across the ovary and notice the number of cells and placentæ. Draw a diagram of this cross-section.
4. It will be seen, then, that the compound pistil of this flower is made up of three coalescent *simple pistils* or *carpels*.

IV. In the pattern flower we noticed that *all the parts of the flower were inserted upon the receptacle and that the parts of different circles were not united* in any case. Sometimes the parts of different circles are united. When this is the case, it is called *adnation*.

V. Examine the flower of some species of Fuchsia (with single flowers) or some species of Evening Primrose (*Oenothera*). Notice : —

1. The calyx (synsepalous), colored (*i.e.* not green), with four lobes.
2. The petals, grown to ("*inserted upon*") the calyx. This is a case of adnation.
3. The stamens, also inserted upon the calyx.
4. The ovary, bearing the "tube" of the calyx upon its summit.

VI. Try and find cases of adnation in the flowers you may see, and notice the differences between the different flowers.

CHAPTER XXII

WIND- AND INSECT-POLLINATION

FEW flowers can be said to be pollinated exclusively either by the wind or by insects, but their special structure adapts them to be pollinated generally by either one or the other.

I. Wind-Pollinated Flowers.— These are usually not showy, that is, neither large nor of conspicuous colors, nor do they possess odors or nectar. The student should examine the flowers of the various Plantains, the Nettles, the Alders (but not the Willows), the Walnuts, Hickory-nuts, Butternuts, the Oaks, and the Birches for examples of the wind-pollinated flowers. This should be done out of doors and the results written in the note-books. The Grasses, particularly Rye, Oats, Timothy, and above all Indian Corn, should be examined. The method in which the anthers are attached to the filaments and the protruding feathery stigmas of the Grasses should be noted and sketched; and the way in which these assist in pollination described.

II. Insect-Pollinated Flowers.— Studies in the field should be made upon this subject also, attention being directed to the following points:—

1. Color.

- (a) What colors are more conspicuous by day?
What by night?

- (b) What proportion of the flowers do you find yellow? blue? red? white? Do these vary during the seasons?
- (c) Observe the flower clusters of the *Lantana*, and of the Clovers, and notice the change of color, as well as position, during the blossoming and withering. Sketch and describe them. What are the reasons for these occurrences?
- (d) Observe flowers whose petals are variegated with stripes of color or ridges. Where do these lead to, and of what use are they?

2. *Odor.*

- (a) With what colors (white, yellow, blue, or red), which you can study, are odors mostly associated?
- (b) Observe that while the odors of most flowers are agreeable to most of us, some flowers have very disagreeable odors: such are the Purple Trillium (*T. erectum*) and the Carrion Flower (*Smilax herbacea*). Such odors attract flies and carrion beetles.

3. *Nectar.*

- (a) Examine the Columbine, Pansy, Larkspur, various Orchids, etc., to see where the nectar is stored; notice that in these cases the honey is out of the reach of insects with short probosces, and can be obtained only by insects with the longer probosces and by humming-birds.
- (b) Examine a Buttercup, and notice the small, deeply colored scales at the base of each petal, under each of which is a pit containing honey. What sort of an insect could utilize this honey?

4. *Special devices.* These are particularly to help the insect do the work properly. We have seen some in the flowers with papilionaceous corollas, in the Larkspur, Pansy, and in imperfect flowers. The number of devices is manifold. Two very striking ones may be studied in the laboratory if the plants are in blossom, viz. : —

- (a) Examine an open flower of some species of *Mimulus* or Monkey Flower (any species, or of *Torenia* of the greenhouses), and notice the stigma. It consists of two flat pieces, an upper and a lower. Selecting a stigma in which the two parts are separated from one another, gently stroke the inner surfaces with a pin or bristle. They will soon begin to move and come together. Look at them from time to time and make a note of how long it takes them to open. (It may require an hour or more.) What is gained to the flower by this device? Write out your answer in your note-books.
- (b) Examine a cluster of flowers of some species of Barberry. Selecting an open flower, notice that the stamens are lying back against the petals. Gently stroke the filament of a stamen and notice its movements. Do the same thing to another. Make a note of this phenomenon, and write out your opinion as to its usefulness to the flower.
- (c) *Kalmia* or Calico-bush (called erroneously Laurel) also shows stamen movements worthy of attention.

5. *Dichogamy*. A more or less complete separation of the sexes is made in perfect flowers by the maturation of the pollen and the stigmas at different times. It is found both in wind- and in insect-pollinated flowers. The effect is to render the flowers *functionally imperfect* although perfect morphologically; in fact, to render them more or less perfectly monœcious. Such cases are very common, occurring in most perfect flowers. There are two kinds of this method of separating the sexes, or *dichogamy*, as it is called:—
- (a) *Proterogyny* (or protogyny), where the stigma matures first; and
 - (b) *Proterandry* (or protandry), where the anthers open before the stigma is receptive (*i.e.* mature).

Dichogamy, $\left\{ \begin{array}{l} \text{Protogyny,} \\ \text{Protandry.} \end{array} \right.$

6. Examine a flower cluster of a species of Figwort (*Scrophularia*) or of the common Plantain, and notice:—
- (a) That in the upper flowers the stigmas are protruded while the anthers are still unopened.
 - (b) In the lower flowers, the anthers are opening, but the stigmas are withered.
 - (c) Is this protogyny or protandry?
7. Examine the flower clusters of a Geranium or some kind of Mallow (*Malva*, *Lavatera*, *Abutilon*, or *Hibiscus*) and notice:—
- (a) That in the upper flowers, the anthers are shedding their pollen, but that the stigmas are not opened, while
 - (b) In the lower flowers, the anthers are empty and the stigmas are open.

(c) Is this protogyny or protandry?

8. *Heterostyly*.

(a) Examine flowers of a number of different plants of the Bluet (*Houstonia cœrulea*) or of some species of Primrose, and notice : —

1. The fact that some flowers have long styles and stamens inserted about half-way up the tube of the corolla, while
2. Others have short styles and the stamens inserted near the top of the tube of the corolla.
3. Explain, if you can, how this structure serves the same purpose as a separation of the sexes in these flowers.
4. (Examine, also, the stigmas and pollen of both kinds of flowers under the compound microscope.)
9. Examine the Purple Loosestrife (*Lythrum Salicaria*) or the Swamp Loosestrife (*Nesæa* or *Decodon*) in the same way, and notice that there are three kinds of flowers, representing three lengths of filament and three lengths of styles. What is the use of this?
10. Examine flowers from a number of plants of *Eschscholtzia* and notice : —
 - (a) The fact that in some flowers two of the four styles are longer than the other two. What advantage does the plant derive from this?

CHAPTER XXIII

SELF-POLLINATION

CROSS-POLLINATION seems to be the rule. Many flowers, however, are so constructed that, if they fail to be cross-pollinated, they are self-pollinated. But such flowers produce fewer and less vigorous seeds than the cross-pollinated flowers. But some flowers are especially constructed for self-pollination alone. They are called *cleistogamous* flowers.

I. Examine the greenish flowers (produced close to the ground) of the Fringed Polygala (*P. paucifolia* and *P. polygama*, of the East or any Pacific Coast species) and notice : —

1. The contrast in color between them and the upper flowers.
2. The fact that fertilization takes place when the flowers are very small, for the ovary begins to enlarge very soon.
3. The fact that the flowers never open.
(Dissection to demonstrate the floral organs is rather too difficult for beginners.)
4. Make sketches and notes.

CHAPTER XXIV

ANTHOTAXY

ANTHOTAXY treats of the arrangement of flowers upon the stem. Flowers are borne either singly or in clusters. The advantage of flowers being brought together into clusters is, that the same pollinating agency, bringing pollen to one flower, may benefit the rest or at least some of them. In this way the flowers "club together," as Grant Allen says, to share favorable pollinating influences. We shall study a few of the more important common arrangements.

I. **The Raceme.**—Examine a flower cluster of the Lily of the Valley, Red-hot-Poker Plant, *Zygadenus*, Currant, or similar plant and notice :—

1. The general shape of the cluster (*elongated*).
2. The *main* stem with
3. The flowers *arranged at different heights*.
4. The order of blossoming, beginning at the base and proceeding towards the top.
5. Examining each flower, notice :—
6. The short stalk, of nearly the same length in each flower.
7. The small leaf (or leaf scale) in whose axil each flower is borne. (Notice that consequently all the flowers are lateral structures.)
8. Make a sketch and diagram to show these points and label the parts, as follows :—
(a) *Peduncle*, the main axis or stem.

- (b) *Pedicels*, the stalks of the individual flowers.
- (c) *Bracts*, the leaves or scales subtending each flower.

II. **The Corymb.**—Examine the flower cluster of a Hawthorn and notice :—

1. The general shape of the cluster (*flat-topped*).
2. The peduncle.
3. The pedicels of different lengths, so as to bring all the flowers to the same level.
4. The order of blossoming. Compare it with that of the raceme.
5. That all the flowers are lateral axillary structures.
6. Make a diagram to show these points.

III. **The Umbel.**—Examine the flower cluster of an Onion or a Pelargonium (the so-called Geranium of the gardens) and notice :—

1. The pedicels of equal length.
2. The fact that they all spring from the same point.
3. Make out the order of blossoming if you can.
4. Make a diagram of an umbel.

IV. **The Compound Umbel.**—Examine the flower cluster of a Carrot, Parsnip, Fennel, Caraway Seed, or Poison Hemlock and notice :—

1. The fact that a number of small umbels are themselves arranged after the fashion of an umbel.
2. Study one *umbellet* (small umbel) as directed in III.
3. Notice the circle of bracts at the base of the umbel (called an *involucre*).
4. The circle of smaller bracts (*bractlets*) at the base of each umbellet (called an *involucel*).

5. Make a diagram to show these points.

V. **The Spike.**—Examine the flower cluster of one of the various species of Plantain and notice :—

1. Its general shape.
2. The order of blossoming.
3. The long peduncle.
4. The *sessile* (*i.e.* without pedicels) flowers. (Lateral, axillary structures here also.)
5. Make a sketch to show this.

VI. **The Spadix.**—Examine the flower cluster (often erroneously called a flower) of the Calla and notice :—

1. The broad white *bract* (called in this case, a *spathe*) at the base of the flower cluster.
2. The general shape of the flower cluster.
3. The peduncle.
4. Whether the flowers are sessile or not. (Lateral and axillary?)
5. The order of blossoming (noticing that the flowers are imperfect with pistillate below and staminate above).
6. The fleshy consistency of the whole cluster.
7. What is the spathe for? Why is it so conspicuous?
8. Make a sketch of the Calla.
9. Compare it, if possible, with the Flamingo Plant or *Anthurium* of the greenhouse and notice the same parts, but also noting the very different color of the spathe.

VII. **The Head.**—Examine the flower cluster of a Red Clover, *Lantana*, or *Verbena* and notice :—

1. The general shape of the cluster.
2. The insertion of the flowers.

3. The order of blossoming.
4. Whether the flowers have pedicels or not.
5. Make a diagram of the cluster studied.

VIII. **Indeterminate and Determinate Anthotaxy.**—The order of blossoming in all the clusters studied thus far, has been practically the same ; that is, from below upward or, in the flattened clusters, from without inward. All arrangements having this order of blossoming are classed under the head of *indeterminate anthotaxy*. But in some clusters, the order of blossoming is just the opposite ; that is, from above downward, or in the case of flat-topped clusters, from within outward. Such arrangements fall under the head of *determinate anthotaxy*. The *cyme* is the most common example.

Another distinction, and the one upon which the order of blossoming depends, is that, in indeterminate anthotaxy, the flowers are all *lateral*, while, in determinate, they are all *terminal*.

IX. **The Cyme.**—Selecting a Begonia (preferably one of the “tuberous” species with lax flower clusters and large flowers), examine several clusters of different ages and notice :—

- 1.. That the central flower blossoms first.
2. That the two axes (one at each side) next the central flower, elongate, bear clusters of buds and that the central bud of each cluster blossoms.
3. That the two axes adjacent to each of these central flowers repeat the same process and so on regularly for several times.
4. Make diagrams to show this.
5. Notice also that all the flowers are terminal upon short branches.

X. In reviewing the work on flower clusters, be careful to consider the following points : —

1. The exact difference between the determinate and indeterminate anthotaxy.
2. What characters have the following indeterminate clusters in common : *raceme*, *corymb*, and *umbel*?
3. How may they be distinguished from one another?
4. What characters have the following indeterminate clusters in common : *spike*, *spadix*, and *head*?
5. How may they be distinguished from one another?
6. How may the group of clusters mentioned in 2 be distinguished from those mentioned in 4?
7. Write out concise (*i.e.* using no unnecessary words) definitions of all the flower clusters you have studied.

XI. Many flowers are not in clusters at all, but occur singly. They may be : —

1. *Terminal* in some cases, as in the Rose, but mostly
2. *Axillary*, at least if considered very carefully.

CHAPTER XXV

METAMORPHOSIS

THUS far everything that we have studied has been either root, stem, or leaf, or a combination of these. The flower itself is nothing more than an *altered branch*, and we may consider briefly the arguments for considering the various floral organs to be simply leaves, modified to perform the special duties of reproducing the plant by seed.

I. Position of the Flower upon the Stem.—Looking back over our study of anthotaxy, we find that the flowers are either terminal (either solitary terminal flowers or in determinate clusters) or lateral and axillary (either solitary axillary flowers, or in indeterminate clusters).

Turning back to our study of buds, we find that they were either terminal or lateral structures and that the ordinary lateral buds were axillary. From leaf buds grow branches; from flower buds grow branches with their leaves altered to form the various parts of the flower.

Consequently we see that *the flower occupies exactly the same position upon the stem which an ordinary branch does.*

II. The parts of the flower follow the laws of phyllotaxy in their arrangement.—The parts of the flower are arranged in whorls, with the whorls alternating in most flowers, and consequently follow the *cyclical* arrangement (see Chapter

VII, § III), even where the phyllotaxy of the plant in general is spiral. But we have in many plants a change from the one arrangement to the other upon the same plant evidenced even by the ordinary foliage leaves.

III. **The parts of the flower grade into one another;** that is, give evidence that they are all modifications of the same kind of structures. The evidence here is of two kinds.

1. (a) Examine the flower of a white Water-Lily (*Nymphaea*).

Passing from the outside, the sepals are partly green and partly white; the white petals grow narrower and begin to show small anthers at their tips; the white portion becomes narrower and narrower until the typical stamens are found.

(b) The Sweet-scented Shrub (*Calycanthus*) shows sepals gradually passing into petals, petals into stamens, and stamens into pistils. It is difficult to tell in some cases whether we are examining stamens or pistils.

2. In double flowers such as Roses, stamens are transformed into petals by cultivation, and in the double Althæa (*Hibiscus Syriaca*) even the stigmas become petaloid; and, upon opening the ovary, the ovules are often found to be changed to petal-like bodies.

(The pupil should examine all double flowers for evidence and make notes.)

IV. **Green Flowers.** — Occasionally Roses, Trilliums, Fig-worts, Buttercups, and other flowers are found, in which some or all of the floral organs are changed into green leaves. Examples of such flowers are to be sought and examined. This is called "reversion to a primitive condition."

V. These four kinds of evidence support the doctrine called *the doctrine of the metamorphosis of parts*, which holds that the *flowering plant* has only three kinds of structures, root, stem, and leaf, and that it produces structures to do all its work by altering (or modifying) one or more of these three parts. We found this to be true in studying the bud scales (Chapter VIII), Protection (Chapter X), Storage (Chapter XI), Devices for Climbing (Chapter XII), Epiphytes, Parasites, and Saprophytes (Chapter XIII), Insectivorous Plants (Chapter XIV), Vegetative Reproduction (Chapter XVI); and now we find that the complicated structures necessary for seed reproduction form no exception.

CHAPTER XXVI

FRUITS

AFTER the two nuclei, the one from the pollen tube and the one in the ovule, have united, important changes take place in the ovule. From the resulting nucleus and the parts immediately surrounding it, the *embryo* is formed while the rest of the ovule is transformed into seed-coats, endosperm, etc. But the ovary surrounding the ovules, also grows and undergoes changes, and, gradually, the ripened structure called the *fruit* is formed. *The fruit is, strictly speaking, the ripened ovary and its contents.*

In many cases, the petals and stamens fall away soon after fertilization is accomplished or remain in a withered condition, but do not undergo any further changes. The calyx often remains without further change during ripening, but may fall away also.

But in many cases, also, one or more of the circles of structures outside the pistils may remain, undergo further growth, and form with the altered ovary and its content of seeds a complex body which is also commonly spoken of as the fruit; even the *receptacle* is sometimes enlarged and made a part of the fruit in this looser sense. Consequently we find a considerable variety of kinds of fruits.

The fruit serves two purposes : —

1. It protects and helps nourish the ripening seeds.
2. It assists in the scattering or *dispersal of the seeds.*

It is especially from this latter point of view that we shall study fruits. It is very necessary that the seeds should be scattered in such a way that the plants produced from them may not grow so near to one another as to be limited for space in which to grow. Some fruits are evidently so constructed as to send their seeds only a short distance, others so as to scatter them to a considerable distance. Some simply expel their seeds to a comparatively small distance from where they were produced, while others make use of animals, of the wind, and of water to send their seeds a greater distance away.

Fruits are classified according to their consistency into *fleshy* and *dry fruits*. Dry fruits are classified into *dehiscent* and *indehiscent*, according to whether they split open or not.

CHAPTER XXVII

FLESHY FRUITS

WE shall be able to find many fruits in which all or a portion of the ripened ovary wall (called in these cases, as well as in those of dry fruits, the *pericarp*) is soft and fleshy. The fruits help to disperse the seeds they contain by being eaten by animals (particularly by birds). In such cases the outer fleshy portion is digested, and the seeds, protected by their own resistant coats or by a hardened portion of the pericarp, remain undigested, pass from the intestine of the animal with the other excreta, and are thus left at a greater or less distance from the places where they were produced.

In studying fleshy fruits we distinguish two general classes : —

1. *Berries*, in which the entire wall is fleshy and
2. *Drupe*s or *Stone Fruits*, in which the outer portion of the pericarp wall is fleshy, but the inner wall is hard and resistant.

We shall study the stone fruit first.

I. **The Drupe.** — Take a ripe Peach, Apricot, Cherry, or Plum, examine it carefully and notice : —

1. The general shape, size, color, odor, etc.
2. The point of attachment.
3. The small protuberance at the other end (where the base of the style joined the ovary).

4. Make a sketch of the fruit studied.
5. Why do these fruits remain hard and green until the seeds are nearly ripe and then become soft and bright-colored?

II. Cut a ripe Peach, Cherry, or Plum into two longitudinal halves and notice : —

1. The outer skin of the pericarp.
2. The fleshy middle portion of the pericarp, called the *sarcocarp*.
3. The inner stony portion of the pericarp, the *putamen*, enclosing
4. The seed, whose seed-coats are thin and delicate.
5. Make a sketch of one of the cut surfaces.

III. The drupes just studied are all formed from the ovary of a simple pistil, whose ovary was one-celled and one-seeded. Drupes occur also in the Huckleberries, Bearberries, Manzanitas, etc., but contain several putamina. In such cases they are distinguished from berries with some difficulty, the putamina looking much like seed-coats.

IV. **The Berry.** — Take a Cranberry, examine it carefully, and notice : —

1. The general shape, size, and color.
2. The short stalk (or the place where it was attached).
3. The four blunt teeth surrounding a hollow at the opposite end. (These are the tips of the sepals which are adherent to the ovary and help to form the pericarp of the fruit.)
4. Make a sketch to show these characters and label.

V. Cut the berry being studied across at the equator and, examining one of the cut surfaces, notice : —

1. The fleshy pericarp enclosing
2. Four spaces (the *cells*), in each of which are
3. Several seeds.
4. Make a sketch of one of the cut surfaces and label.

VI. Gooseberries, Currants, Bananas, Tomatoes, and Grapes are also good typical berries (in the last two the pericarp consists of the changed ovary wall simply, while in the others, as in the Cranberry, the pericarp is the ovary wall plus the adherent calyx-tube), but the seeds appear buried in fleshy material. There are also several kinds of fruits that are really berries and yet have certain peculiarities. Such are the *pome*, the *hesperidium*, and the *pepo*.

VII. **The Pome.** — Examine a ripe Apple and notice : —

1. Its general size, shape, color, and odor. *white*
2. The stalk at one end.
3. The five sepal-lobes in the depression at the other. *Brown*
inner
4. Make a sketch and label.

VIII. Cut the Apple across at the middle and, examining the cut surface carefully, notice : —

1. The outline of the section.
2. The five openings (*cells*) each with a papery wall. (This can be demonstrated by prying it away from the flesh. It represents the wall of the ovary and forms with No. 3 the "core" of the apple.) *on the outside*
3. The fleshy portion outside of No. 2, bounded by a greenish line from *the outside*
4. The outer flesh bounded upon the outside by *the outside*
5. The outside skin.
6. Make a sketch of the section and label the parts.
7. (Notice the tough seed-coats.)

IX. Cut the pome being studied into two halves (length-wise) and, examining one of the cut surfaces, notice : —

1. The general shape of the surface. *W. 100%*
2. The cells and the seeds.
3. The papery core.
4. The irregular core flesh.
5. The outer flesh.
6. The outer skin.
7. Make a sketch of the cut surface and label.

orange and orange
X. The **Hesperidium**. — Take a Lemon or an Orange, examine, and notice : —

1. The general shape, size, color, and odor.
2. The point at which it was attached.
3. The (protuberance at the other end) *of* representing the (lower end) of the style.
4. Make a sketch of the fruit studied. *1-6-8*

XI. Cut the Lemon or Orange across the middle and, examining one of the cut surfaces, notice : —

1. The outer rather thick "rind." *2. 0.2 100%*
2. The inner fleshy portion separated into several distinct portions by walls (septa), running from the rind to the centre. (These are the cells of the fruit.)
3. The juicy pulp filling the cells, in which (in most Lemons and Oranges) may be found
4. The seeds. Notice the character of the seed-coats and the attachment of the seeds.
5. Make a diagram of the cross-section and label the parts.

Central axis (100% of white)
XII. The **Pepo**. — Take a Cucumber, Melon, Gourd, or Pumpkin, examine carefully, and notice : —

1. The general shape, size, color, and odor.
2. The point of attachment.
3. Make a sketch of the fruit being studied.

XIII. Cut the pepo being studied across the middle and, examining one of the cut surfaces carefully, notice : —

1. The outer, tougher portion of the "rind."
2. The softer inner portion.
3. The seeds imbedded in a pulpy mass.
4. The attachments of the seeds.
5. The resistant seed-coats.
6. Make a sketch of the section studied.

XIV. Have you ever seen animals eating fleshy fruits? If so, write down what kinds of animals were doing the eating and what kinds of fleshy fruits were being eaten. How does this help the dissemination of the seeds?

- surface of rind

small

CHAPTER XXVIII

DRY DEHISCENT FRUITS

DEHISCENT fruits are those which split open to release or even expel the seeds. We may distinguish two classes : —

1. *Explosive Fruits*, which forcibly expel some or all of their seeds, sending them out into the air.
2. Those which simply open and allow the seeds to fall out, leaving them to be dispersed by other means.

EXPLOSIVE FRUITS

I. Take the ripening pods of some member of the Pea Family, such as Wistaria, Pea, Bean (with less fleshy pods), etc., and, leaving them in a dry place, examine them from time to time. Sooner or later, they will be found to have split longitudinally, each half or *valve* of the pod will be found to have twisted itself and to have thrown most of the seeds to some distance.

Make sketches and notes to illustrate this.

II. Take also the ripe pods of some species of Violet and watch them in the same way.

III. Take plants of the garden Balsam (*Impatiens*), or of *Oxalis*, and touch the ripe fruits.

Notice how they suddenly open and eject the seeds.

Make notes and sketches.

METHODS OF DEHISCENCE

The fruit produced by the ripening of a compound pistil is called a capsule, if dry and dehiscent. The capsules open to release the seeds in several different ways.

IV. Loculicidal Dehiscence. — Take capsules of *Iris*, *Funkia* or Day Lily, *Althæa*, *Hibiscus*, *Gerardia*, etc., which have split open and notice how the splitting has taken place.

1. The splitting is longitudinal.
2. The split is directly along the middle line of the outer wall of one of the cells (*loculi*) of the capsule.
3. The partitions remain coherent with the outer walls and separate from one another at the centre.
4. Make a diagram—or rather a ground plan—to show this method of dehiscence.

V. Septicidal Dehiscence. — Take capsules of *Azalea*, *Rhododendron*, Turtle Head (*Chelone*), or St. John's Wort, which have split open and notice how the splitting has taken place.

1. The splitting is longitudinal.
2. Each partition (*septum*) is split into two thin pieces.
3. The partitions remain adherent to the outer walls and separate from each other at the centre.
4. Make a ground plan of this method of dehiscence and show how it differs from the loculicidal method.

VI. Septifragal Dehiscence. — Take capsules of the Morning Glory which have become thoroughly dried, but which are either just splitting or which are still whole,

and using a pin or needle, gently pry off the outer parts.
Notice : —

1. That the splitting is longitudinal.
2. That the splitting is directly along the line of the partitions.
3. That the three partitions (*septa*) are left standing (by the complete falling away of the valves).
4. Make a diagram to show this method of dehiscence and contrast it with each of the methods just studied.

VII. **Circumscissile Dehiscence.** — Take plants of the Common Pimpernel (*Anagallis*), the *Portulaca* of the gardens, or the Purslane, which have ripe, dry capsules and examine the method of splitting.

1. The splitting is horizontal (at the equator, so to speak, of the capsule).
2. The upper part falls off, leaving
3. The lower portion as a sort of cup still holding most of the seeds.
4. Make sketches to show this method of dehiscence.

VIII. **Dehiscence by Pores.** — Examine dry capsules of some Poppy and notice : —

1. The general shape.
2. The swollen portion.
3. The terminal discoid portion with scalloped edges (the remains of the stigmatic portion).
4. The row of small holes or pores at the top of the swollen portion and just under the edge of the disk.
5. Make sketches.
6. How do the pores arise? (For determining this, examine, if possible, ripe capsules just forming pores.)

IX. Determine, wherever possible, what advantage each method of dehiscence has for the particular kind of plant in which it is found.

X. Write out concise and clear definitions for the kinds of dehiscence you have studied.

CHAPTER XXIX

DRY INDEHISCENT FRUITS

THE dry fruits (that is, those whose pericarp at maturity is not fleshy) which do not open, remain to be considered. If we were to go into the classification of such fruits, we should need to consider in each case whether it resulted from the ripening of a simple or of a compound pistil, distinguishing two classes as follows :—

1. *Nuts*, dry indehiscent fruits from compound pistils.
2. *Achenes*, dry indehiscent fruits from simple pistils.

But without considering this matter too carefully, we shall devote our attention to the different methods and agencies employed by these fruits to travel abroad and to carry the seeds contained within them to some more or less distant place.

The three different agencies most commonly employed are :—

1. Animals of various kinds.
2. The wind.
3. Water.

CHAPTER XXX

SEED DISPERSAL BY ANIMALS

WE have seen how fleshy fruits may be dispersed or scattered abroad by animals, but they do not as a rule eat dry fruits unless it is for the sake of the seeds, in which case, of course, the seed is crushed and digested, and ceases to exist. But most dry fruits, achenes or even dry fruits dehiscent only after a considerable interval of time, have appendages of various kinds which catch hold of animals and are transported by them.

I. Take a fruit of the Common Clotbur (*Xanthium*) and notice : —

1. Its shape, size, color, and consistency.
2. The two strong spines or hooks at the top.
3. The smaller hooks thickly placed upon the sides.
4. Make a sketch of this "fruit," or more properly *bur*.
5. The involucre (enclosing two achenes) is modified to form the bur. A similar case is the Common Burdock.

II. Examine an achene of the Beggar-ticks (*Bidens*) and notice : —

1. The body of the achene, its shape, etc.
2. The terminal bristles (varying in number in different species) provided with

3. Small downward-pointing hooks or barbs (readily visible under a lens).
4. Make an enlarged sketch to show these points.

III. Examine the fruit of the Common Bedstraw or Goose Cleavers and notice :—

1. The two small rounded portions (called *mericarps*).
2. The hooked bristles with which each is provided.
3. Make a sketch of this fruit.

IV. Gather and study all the specimens of fruits which you can find provided with organs for attachment to animals.

V. But some fruits possess spines which do not appear to serve the purpose of aiding dispersal by animals. The Chestnut, Chinquapin, Beechnut, and Thorn Apple (*Datura*) are provided with spines surrounding the fruit, but the covering opens, and the seeds drop out. The spines in these cases probably protect the seeds, while ripening, from squirrels and such animals. (Some ripening berries have spines which fall off when the seeds are mature.)

VI. Small animals, such as squirrels, store away nuts and grain in the ground and forget the place or are killed. The seeds of these fruits may germinate. This is a very effective means for seed dispersal in some regions, but of rarer occurrence than the other methods. Ants, too, store seeds and fruits in their underground homes.

CHAPTER XXXI

SEED DISPERSAL BY WIND

IN order that seeds may be carried any appreciable distance by the wind, they must be rendered buoyant. The structures existing for this purpose may, for the most part, be classed under three heads, — *wings*, *tufts of hairs*, and *bladders*. These are more often, perhaps, attached to the fruits, but may, also, be attached directly to the seeds.

I. **Samara, or Key Fruit.** — Examine dry, ripe fruits of Ash, Elm, Ailanthus, or Maple and notice : —

1. The swollen seed-bearing portion and
2. The flattened wing.
3. Throw up some specimens into the air and notice the twirling motion which helps to support them for some distance.
4. Make a sketch of the fruit studied, to show the parts and describe the motion in the air.

II. **Winged Seeds.** — Examine some of the dry seeds of Catalpa, Yam (*Dioscorea*), Butter-and-Eggs (*Linaria*), Trumpet Creeper, Day Lily (*Funkia*), or of the Pine or Cypress, and notice : —

1. The *compressed* seed-bearing portion, with
2. The broader or narrower wing.
3. Make a sketch to show these characters.

III. **Fruits with Tufts of Hairs.**—The achenes of many of the Composite Family, particularly such as those of the Dandelion (*Taraxacum*), or the western Troximons (*Agoseris*), are provided with parasol-shaped tufts which act after the fashion of a parachute. The student should examine and draw as many of these as possible. (Examine also ripe Thistle Heads.)

IV. **Seeds with Tufts of Hairs.**—Examine the dry seeds of the Milkweed or of Cotton and notice the arrangement of hairs and how they assist the seed in being carried by the wind. Make sketches.

V. **Bladdery Fruits.**—Examine the ripe and dry fruits of the Bladder Nut (*Staphylea*), of *Isomeris*, or of some *Astragalus* species with swollen pods and notice:—

1. The general size, shape, color, etc.
2. The much distended ovary wall.
3. The buoyancy of the fruit.
4. Make sketches.

VI. **Examine the dry, ripe fruits of the Hop, Hop Hornbeam, or of the Ground Cherry (*Physalis*) and notice:—**

1. The bladdery portion, either an enlarged investing bract (Hop) or the enlarged calyx (*Physalis*).
2. Make sketches and notes.

VII. **Tumble Weeds.**—Many species of plants which are annuals dry up entirely upon the ripening of the seeds, break away from their attachment, and are rolled about from place to place by winds. They drop seeds as they travel and thus often disperse their seeds over a very wide area.

CHAPTER XXXII

SEED DISPERSAL BY WATER

MANY marsh plants growing near running or even quiet waters, upon the margins of the ocean, or in the water itself, depend in most cases upon the currents of water or upon the breezes at the surface of the water for their dispersal. They are usually, therefore, rendered buoyant in some way or other.

I. Examine a Cocoanut, still retaining its husk, and notice :—

1. The general shape, size, color, etc.
2. The attached end.
3. The opposite pointed end.
4. The three blunt angles (longitudinal).
5. Make a sketch to show these points.

II. In a Cocoanut which has been cut into two longitudinal halves, examine one of the cut surfaces and notice :—

1. The outer thin, firm, smooth skin.
2. The fibrous portion of the husk.
3. The shell (seed-coats) of the nut.
4. The "meat" (endosperm) of the seed.
5. The small embryo under the "soft eye" at one end.
6. Make a sketch of one of the cut surfaces.

III. Examine the bladdery fruits of some Sedge or the seeds of the Water-Lily, if obtainable and notice their buoyancy in water.

CHAPTER XXXIII

SPORE REPRODUCTION

THE plants possessing reproduction by spores are usually much more simple than those which reproduce by seeds. Many of them are decidedly microscopic and hardly, if at all, visible except under the lenses of the compound microscope. But others, such as the ferns and the mosses, are larger and more complicated plants, approaching very nearly to the seed-plants in the degree of the complexity of their structure and their size.

The principal groups of plants which reproduce by spores are the Ferns (in the broadest sense of the word), the Mosses, the Sea-weeds or Algæ, the Lichens, and the Fungi (including Toadstools, Puff-balls, Mildews, Rusts, Smuts, and Moulds).

Spores are of several kinds, and need extended study with the compound microscope and more complicated methods than we have been using. We may, however, study several kinds in a rough sort of way.

I. Examine a Fern Plant removed from the soil, and notice :—

1. The stem (usually underground).
2. The leaves, their shape, size, etc.
3. The dots upon the backs of the leaves. These are the *sori*, which are of different shapes in different Ferns and which, in some cases, are covered partially by a thin skin, called the *indusium*.
4. Make a sketch of the Fern Plant to show these points.

II. Selecting a leaf upon which the sori are growing, remove a few sori and examine them under the lens of the dissecting microscope. Notice : —

1. The small stalked bodies, *sporangia* or *spore cases*, most of them split open at one side.
2. The very small brown bodies scattered about, which are the spores.

(These points will show much more plainly under a compound microscope. Simply place the sporangia, spores, etc., upon a glass slide, moisten with strong alcohol, add a drop of water, and cover with a cover glass.)

III. Examining the fruiting plants of some Moss such as the Hair-Cap Moss (*Polytrichum*) or *Funaria*, notice : —

1. The rooting portion.
2. The stem with
3. Its leaves.
4. The capsule upon its stalk or *pedicel*.
5. Make a sketch of the Moss Plant.

IV. Examine the capsule more carefully with the aid of the lens and notice : —

1. The *calyptra* (hairy in *Polytrichum* but smooth, thin, and hyaline in most Mosses). Remove it and examine—
2. The *operculum*, a small cap, which may be picked or pried off, and then appears
3. The *peristome*, a row of teeth about the mouth of the capsule proper.
4. Make sketches of these various parts.

Take a thoroughly dry capsule and, removing, if necessary, the calyptra and operculum, tear open the

body and examine the fine, dust-like, greenish *spores* (with the compound microscope, if possible).

V. Take fresh specimens of the Common Mushroom (or any Toadstool with gills) which has thoroughly expanded and notice :—

1. The stem or *stipe*.
2. The expanded top, the *pileus*, upon the under side of which are found
3. The *gills* or *lamellæ*, numerous thin plates, colored, and radiating from the stipe outward.
4. Make sketches.

VI. Removing the stipe, place the pileus, with gills downward upon a piece of white paper and cover with a bell glass or cake cover. After several hours a "spore print" will be found upon the paper resembling the arrangement of the gills. Examine the spores of this print with a lens, or with the compound microscope. Notice the color and minute size of the spores. Make a sketch of the spore print.

VII. Examine again, or review, the Bread Mould (confer Chapter XIII, § VIII), and notice the sporangia and spores.

VIII. Our study of spores has necessarily been very slight and fragmentary. We find, however, that they differ from seeds in two principal respects :—

1. Their minuteness. (Of course, some seeds are very small for seeds and some spores are very large for spores, yet their very much smaller size will usually distinguish spores from seeds.)
2. The fact that the spores are simple practically homogeneous bodies without an *embryo*. This can be seen under a compound microscope and when the spores

germinate. Such spores as those of the Bread Mould and of the Mushroom might not be expected to contain an embryo, but when we find no embryo in those of mosses and ferns, we see the necessity for distinguishing spore from seed reproduction. If we could pursue the subject further, we should see further reasons for emphasizing this distinction.

IX. Spores are never preceded by any structures which can be called, botanically, flowers, that is, by structures containing stamens, or pistils, or both.

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APPENDIX I

SUGGESTIONS TO STUDENTS

Spirit of Study. — The students should attempt to get at the reasons which lead to the selection of a natural science as a portion of their course of study. It is not only a matter of acquiring a certain amount of information which will be a source both of profit and of pleasure in the future, but also to train certain faculties to act in an orderly and effective manner. To learn to observe carefully is a matter of the utmost importance in all the ordinary things of life. Many of our mistakes are the direct result of hasty observation and inference. Without accurate observation, we can have no certainty as to the accuracy of our inferences and whenever we think it over we realize that even the simple matter of recognizing an object, its shape, etc., is really a matter of inference. But after we make out what the shape and general structure of an object is, we have still to infer from these details its use, relations to other objects, etc.

Consequently, in laboratory work of any kind, the name of the object or of its parts are purely matters of convenience, to assist the memory and to enable us to talk to others concerning these things, but the principal matter in hand is to notice every detail and variation in form both of the object being studied and of its parts; then, from this as a basis, to reason out why the object and its parts are constructed as they are; and finally to make a permanent record, both of the

observations and of the conclusions arrived at, in such a way that the memory may be readily refreshed concerning them.

Students should look to the teacher for inspiration as to the proper spirit with which to regard their work. Many times the reason why particular attention is paid to certain things may not be apparent, but this should furnish no excuse for not carrying the work through thoroughly as directed. If the reason is obscure at the time, we should have perfect confidence that it will be revealed later on ; as the work proceeds, the plan underlying it will unfold itself, and we shall finally find ourselves in possession of the whole and recognize the value of each of its parts. We should entrust ourselves to the teacher's guidance with perfect faith that all which now seems dark and hidden will be cleared away before the course is completed.

Instruments.— Few instruments are absolutely necessary for the work planned in this book. The pupil should, however, possess the following : —

Laboratory note-book,
Pencils and eraser,
Pair of small forceps,
Scalpel or penknife,
Pocket lens or dissecting microscope,
Pair of needles in handles.

Note-Book.— The note-book should be of fair size. One with a page about 10 inches long and 6 to 8 inches wide is preferred by the writer. The paper should be white, unruled, fairly heavy, and with sufficient gloss to take the mark of the pencil readily, but not so much so, as to make erasing difficult.

Pencils.— A fairly hard pencil should be used, certainly hard enough so that it will be possible to keep it well

sharpened. Some students will need to use a harder pencil than others and each will need to experiment a little perhaps. The teacher can advise in such matters.

Eraser. — A good soft rubber eraser will answer very well, but students may consult their own tastes in this matter.

Forceps. — For handling small objects, even very slender fingers are too large and clumsy, and the student should possess a pair of small forceps for this purpose. Steel ones are the best, but brass ones may be used. The tips of the forceps should be fairly slender, and the points should be roughened (not toothed) upon the inside so as to grasp the object firmly. The "spring" of the forceps should be fairly but not too strong. Too strong a spring tires the fingers unnecessarily, while too weak a spring (so that the forceps do not open promptly) renders them practically useless.

Scalpel. — A small scalpel is most useful for cutting small objects. A penknife, provided the blades are kept sharp, will do very well. A small razor with one side ground nearly flat is perhaps even more useful at times than either the penknife or scalpel.

Pocket Lens. — A pocket magnifying-glass mounted in metal or hard rubber (or better a series of two or three mounted lenses) is indispensable for the examination of small parts. Almost any of the common ones in the market will do. A simple dissecting microscope is, however, very much more effective. Some of the cheaper ones will answer very well, but the only really satisfactory one, is one possessing besides a good stage (upon which the object may be placed) and a good adjustable arm for carrying the lens, also a mirror, adjustable to any angle. (Such a model as the "Educational Dissecting Microscope" of the Bausch and Lomb Optical Company of Rochester, N.Y.).

Dissecting Needles. — For use with the dissecting micro-

scope the student will need a pair of needles with handles. They may be purchased already made, or they may be prepared readily by forcing the "eye" end of a needle into some such object as the wooden portion of a penholder. The needles should not be either very coarse or very fine.

Drawing.—The student should not begin to draw the object until he is sure that he knows what he is to represent. Examine the object thoroughly, make out the points called for in the directions and then draw the object in such a position that these structures or details asked for may be brought out most clearly and advantageously. It is the greatest of all mistakes to start to draw the object before it has been thoroughly examined.

The size of the drawing depends partly upon the size of the object and partly upon the number and nature of the details to be represented. Large objects must be reduced in the drawing in order to be represented at all, while smaller objects must be enlarged or the details of structure either cannot be represented at all or will be so small and crowded together as to make their recognition difficult.

The outline of the object and of its parts must be sharp and clear. The drawings made in this course are to represent the objects, and not to suggest them. Consequently, shading should be avoided as a usual thing unless the student has considerable skill in that line of work. The shading done by the student usually obscures the details of structure without adding anything either to the scientific or the artistic worth of the drawing. Good, continuous, bold lines are the best. Sketchy, disconnected, indefinite outlines are to be avoided and yet these are the ones which the student usually draws unless a special effort is made to avoid them.

While the size of the drawing may suit the details to be

represented and the area of the page used, the *relative proportions* of the object should be represented as accurately as possible. Especially this matter needs attention, when the drawings are either enlarged or reduced copies of the object. The relative curvature of the different lines and the accuracy of the angles go hand in hand with proper general proportions, and if the student will try to keep these points carefully in mind, his success in drawing will be greater than it could possibly be otherwise.

Labelling and Notes. — Drawings and notes are for future use, it must be remembered, and not introduced simply to give the student something to do, as is sometimes thought. He should represent accurately, concisely, and clearly the results of his study and be able to recall the work in its detail to his mind at any time, as well as to make his results comprehensible to another. Each drawing should be made large enough and its parts distinct enough, to call up a mental picture, perceptible, in most of its details at least, at a glance. This must be borne in mind, also, in labelling the drawings.

1. Label the entire drawing, stating what it represents ; how much enlarged or reduced.
2. Label each of the parts so distinctly that you may not get two names mixed ; nor apply them to the same part ; nor have to turn the drawing round one way to read some names, and other ways to read others.
3. Leave a space about the drawing with its labelling and place your notes near to it, but not crowded up to it.

As to notes, the questions asked in the book should be answered in regular order and anything shown by the specimen, but not by the drawing, should be written down.

Say what you have to say in as few words as possible consistent with clearness and completeness. Let your notes be concise but to the point, but do not let conciseness interfere with the completeness of your statement. See to it, that your note is worded in such a way as to convey to others whatever it should to you.

APPENDIX II

SUGGESTIONS TO TEACHERS

INTRODUCTORY

THIS little book was written perhaps more for the teachers than for the pupils. Many teachers ask to have some book recommended which will give to them a definite idea of what to do in an elementary course in laboratory practice suitable for the secondary schools. Many teachers are troubled about the method of teaching to be pursued, the amount of ground to be covered, and the materials to be used. The writer has attempted to indicate these in the outline for the student, but feels that he may be able to help many teachers by adding, in this appendix, certain additional directions not to be incorporated into the outline without confusing the student.

Method and Spirit of Instruction.—The teacher may read what is said to the student under the head "Spirit," and also what has been said in the preface upon this point. The ideal way is to teach the student without any book, giving him the object, requiring him to work out the structure and make the proper inferences, aiding him by means of questions designed to stimulate his thoughts and to lead him in the proper direction. But many teachers have too many students and too little time to apply this method, and must use the outline.

The outline needs a good teacher to be really effective. The teacher should be enthusiastic, that is, should enter

thoroughly into the spirit of the nature-study proposed. The plant should be to the teacher, a living thing whose life-history is a reality and he must contrive to raise the minds of his pupils above the drudgery of the work to the lessons to be drawn from it. No book can take the place of the teacher ; it can only assist and counsel.

The outline will admit of much amplification in most subjects, and the teacher will find, even in using it, much chance for original methods and subject matter.

Material. — The selection of material has been made with much care by the writer and he believes that he has succeeded, in almost every case, in recommending something available throughout the more populous portions of this country, from ocean to ocean. On account of the wide diversity in flora, the writer has recommended garden plants wherever possible. The teacher should become acquainted with the local flora, however, and study it with reference to the particular needs of the laboratory instruction. Such a knowledge will enable the teacher to introduce material, often more suitable than that recommended or to substitute one thing for another which is not accessible for the time being.

Preserved material must necessarily be used, instead of living, in many cases. Many things, such as leaves, twigs with buds, dry fruits, etc., may be simply dried and laid away ; but flowers, fleshy fruits, etc., must be preserved in liquid. One of the best preservatives is *Formalin*¹ or *Formalose*, a 40 % solution of Formaldehyde. It is a clear liquid with a penetrating and irritating odor, and is prepared for use by mixing one or two parts (by measure) with 100 parts

¹ Any druggist can readily obtain the Formalin, Formalose, or 40% Formaldehyde, all three being practically the same article under different trade names.

of water (distilled water is best, but any clean water will do). The best jars in which to store materials, are, in the writer's estimation, the "*Lightning*" or the "*Hero*" preserve jars which come in half-gallon, quart, pint, and half-pint sizes. In such jars specimens of flowers, fruits, buds etc., may be preserved for dissection, or insectivorous plants, parasites, etc., may be stored for class demonstration.

A collection of material put up in these ways, either dried or in liquid, especially of things likely to be unobtainable at the time when they are wanted, will greatly facilitate the teacher's work and, in the suggestions concerning the particular chapters, certain farther suggestions will be given. Living material is, in general, much preferable if it can be obtained.

Reading.—The teacher should do as much reading as possible to broaden his horizon and a list of books is given below with comments. Under the notes upon each chapter which are to follow, special references will be given and it will be well to recommend some of these particular references to the pupils; but usually after their laboratory work upon the special object is completed.

Every teacher should have ready access to, and make full use of, the following:—

Kerner and Oliver.¹ The Natural History of Plants. 2 volumes (4 parts). Henry Holt & Co. New York. 1895.

Lubbock (John). Flowers, Fruits, and Leaves. Macmillan & Co. London and New York. 1894.

Lubbock (John). A Contribution to our Knowledge of Seedlings. 2 volumes. Kegan Paul, French, Trübner, & Co. London. 1892.

¹ This, although an expensive book (about \$15.00), is really indispensable. The abundant and excellent illustrations greatly increase its usefulness.

- Gaye (Selina)*. The Great World's Farm. (2d Edition.) Macmillan & Co. London and New York. 1894.
- Hardinge (E. M.)*. With the Wild Flowers. The Baker and Taylor Co. New York. 1894.
- Allen (Grant)*. The Story of the Plants. D. Appleton & Co. New York. 1895.
- Weed (Clarence Moores)*.¹ Ten New England Blossoms and their Insect Visitors. Houghton, Mifflin & Co. Boston and New York. 1895.

There is much more to be gained by having a few good books and making their contents thoroughly familiar to ourselves, than having a whole library simply for superficial acquaintance. The writer has recommended these few books because of the spirit in which they are written, as well as the subject matter. The teacher may look to them for inspiration, and not only inspiration in a general way, but also in a particular way, with reference to special objects for his own study and that of his class. They, also, of themselves will indicate farther reading.

The teacher will do well to have access to a certain number of text-books, especially those treating the subject wholly or partially from a laboratory standpoint.

Some of the more recent and most suggestive are the following :—

- Spalding (Volney M.)*. Guide to the Study of Common Plants. An Introduction to Botany. D. C. Heath & Co. Boston. 1894.
- Darwin (Francis)*. The Elements of Botany. Macmillan & Co. New York. 1895.
- Bergen (J. V.)*. Elements of Botany. Ginn & Co. Boston and London. 1896.

¹ Although this refers to New England blossoms, yet plants very nearly related to several of them being found in most parts of the country, its usefulness is not confined to that particular corner of the United States.

For various morphological questions and especially, for definitions, both teacher and students should consult Gray's well-known text-books—with the glossaries. The writer fully believes that the students should be taught to define and to interpret definitions, and that it is well for them to consult several glossaries and dictionaries; comparing and selecting the good definitions.

Beyond these books are many others, but the writer believes that this list will be sufficient for a beginning and that by these books others will be suggested.

Reviews.—The teacher should try to review the work of each chapter with the students at the close of the work upon it. Quizzing upon the special points brought out and any questions bearing upon them, help in this. Each chapter should be a sort of unit in the minds of the students, and the inter-relationships of the various units making up the book should be brought out and emphasized.

Time.—Each laboratory session should be at least an hour and a half long. Two hours is about the best laboratory period for beginners. Three times a week is about the proper frequency for laboratory exercises. If a course is to run through the year, it should begin, of course, at the beginning of the year, *i.e.* in most cases in the late summer or early autumn. By properly preparing certain materials ahead, the course as laid out in this volume may be given at almost any time of the year and a considerable portion of the material be procured in a living condition.

Laboratories.—If the laboratory can have tall, wide windows facing mostly to the north, it will possess more advantages than any other. But almost any airy and well-lighted room will serve very well for students beginning in this simple way.

Laboratory Equipment.—The laboratory should possess

tables and chairs conveniently proportioned and arranged so that each pupil's place may be as well lighted as possible. If dissecting microscopes such as those recommended on page 133 can be supplied by the institution, the work will be much facilitated. Each institution should possess at least one compound microscope with powers ranging from 65 to 500 diameters, for demonstrating points unsatisfactorily brought out under the lenses of the simple microscope. However, most of the details called for in the laboratory directions may be fairly satisfactorily demonstrated under the lenses of a good dissecting microscope.

CHAPTER I

SEEDS

General Reading

Kerner and Oliver, Volume II, Part 1, pp. 420-427.

Gray, Elements of Botany, pp. 15-26 and 125-128; Text-book, pp. 9-27 and 305-314.

Lubbock, Seedlings, Volume I, pp. 4-8.

THE teacher should allow the laboratory work upon seeds to proceed very slowly, taking care that the students make their observations very carefully, finishing the work called for by one paragraph before proceeding to that demanded by the next. Very careful attention should be paid to the manner in which the drawings of the different seeds and their contents are made. They are very easy objects for the most part; each detail can be plainly indicated and labelled. If the student begins his work properly, the future study will be made easier and better.

I. If a Bean pod is not available, any leguminose pod resembling it will do.

II. Beans should be soaked six to twelve hours, until fully swollen out. The larger "colored" Beans are the best ones for study; but Lima Beans show all parts, especially the plumules, very well.

4. *Strophiole*; read Gray's Text-book, p. 308, § 596.
3, 5, 6, etc. *Hilum, Rhaphe, Chalaza, Micropyle*; read Gray's Text-book, p. 305, § 588.

VII. Castor Bean. Read *Bastin*, Laboratory Exercises in Botany (Philadelphia, 1895, W. B. Saunders), pp. 235-239 (with figures).

1. The Castor Beans in the market are of two kinds, large and small. The larger ones are better. They do not need soaking as a usual thing.
2. Read *Lubbock*, Flowers, Fruits, and Leaves, pp. 93-95.

IX. Read *Gray*, Elements, p. 21, or Text-book, pp. 13, 14.

X. Read *Gray*, Elements, pp. 25, 26, and Text-book, pp. 25, 26.

Corn should be soaked in warm water at least thirty-six hours, to become well swollen.

XIII. Read *Gray*, Elements, p. 24.

XV. Read *Gray*, Elements, pp. 23, 24, and Text-book, p. 23.

"Pine Nuts," of the Piñon or Digger Pines, may be obtained from the markets of many western and Californian cities in the autumn, and even from the New York markets

at times. But teachers may obtain, through seedsmen, the seeds of *Pinus Pinea*, *P. Cembra*, *P. Lambertiana*, *P. edulis*, or *P. Sabiana*, all of which are large and good. The seeds do not need soaking at all in water. They are better without it.

XVIII and XIX. The teacher should not confine himself to the tables, summaries, and lists of questions appended to various chapters, but should ask all sorts of questions to develop and implant the subject in the student's mind.

XIX. As supplementary work, the students may examine thin sections of the Bean, Castor Bean, etc., under the compound microscope, and learn to apply simple tests for starch, cellulose, proteids, oils, etc.

CHAPTER II

SEEDLINGS

General Reading

Kerner and Oliver, Volume I, Part 2, pp. 598-623 (and p. 650 under hypocotyl = caulicle).

Lubbock, Seedlings, especially Volume I, pp. 8-77.

Gray, Elements, pp. 15-26; Text-book, pp. 9-27.

Gaye, The Great World's Farm, pp. 277-299.

I, II, III. Early Peas are soaked over night, then placed upon cotton which is slightly dampened, covered, and kept in a room at about 70-75° F. The caulicle will begin to protrude in about three days.

Beans need about five days.

Corn (soaked thirty-six hours) needs about five days.

Morning Glory (soaked over night) needs about three days.

Onion (soaked over night) needs from eight to ten days.

The caulicle is the first organ to protrude beyond the seed-coats in almost all ordinary seeds. A detailed consultation of Lubbock's Seedlings will show this.

IV, V. It is well to plant in loose soil (or sawdust) about three lots of well-soaked Beans and Peas. The first lot should be planted about three weeks before they are needed; the second lot a week later; the third lot about a week before they are needed. In regard to such matters as having seedlings in good condition, *i.e.* particularly in the right stages for class work, a little experimentation on the part of the teacher will afford a much more satisfactory basis for the teacher than anything else. Seeds vary and conditions vary. A good florist, to advise with the teacher, or even to undertake the work of supplying the materials, will be a great help. The student, however, should have a chance to watch the seedlings as they develop.

VI. Castor Beans should be soaked in warm water for about twenty-four hours, sown in pots or a box of loose earth, about four weeks before they are wanted. They usually start growing one or two at a time, so that after three or four weeks, all stages in germination may be represented in the same pot. The teacher should request the students to compare the caulicle and cotyledons in a well-grown seedling with those organs in the embryo, as regards both size and color. The adult leaf mentioned under 8, may be a pressed leaf, if fresh ones are not available.

VII. What was said of Peas and Beans, applies as well to Indian Corn.

VIII. Onion Seedlings need about twenty days for the cotyledon to develop well and to pull the seed-coats out of the ground, and a week or two longer before any plumule will show.

IX. Pine Seedlings are not very easy to obtain. The smaller seeds (of such species as *Pinus Laricio* and *P. Austriaca*), after soaking for about forty-eight hours, were planted and began to appear in eighteen to twenty days; but the larger seeds (of *P. Lambertiana* and *P. Pinea*) did not appear until after thirty (*P. Pinea*) to fifty-three days (*P. Lambertiana*). Pine seeds may be obtained from the larger seed dealers, but few out of many sown are likely to germinate.

CHAPTER III

ROOTS

General Reading

Kerner and Oliver, Volume I, Part 2, pp. 749-767; I, Part 1, pp. 82-99.

Allen, The Story of the Plants, pp. 53-63.

Gray, Text-book, pp. 27-33.

Gaye, The Great World's Farm, pp. 124-148.

I. This use of "secondary root" and of "adventitious root" is contrary to that of Gray's Text-book, but is more in accord with the general usage of secondary and adventitious.

II. Squash Seedlings are not always easy to raise within doors. Care should be taken to get "sound" seed and not to keep the soil too damp. A few good seedlings preserved

in formalin solution will furnish a proper safeguard against the failure to grow.

III. The "base of the adult cornstalk" may simply be dried and the same specimens used year after year.

IV. Read *Kerner and Oliver*, Volume I, Part 1, pp. 86-91. The student may examine the root-hairs under the lenses of the compound microscope and even study the finer structure of the whole root from the point of view of the function of each of the different tissues.

CHAPTER IV

STEMS

General Reading

Kerner and Oliver, Volume I, Part 2, pp. 710-723, and 724-736; also 465-482.

Gray, Text-book, pp. 45-51 (top) and 69-85.

Allen, *The Story of the Plants*, pp. 161-182.

I. Cosmos stem will do equally well. The pieces may be dried and kept in that condition until a few hours before using, when they should be placed in boiling water and allowed to stay there until it becomes cool. Formalin material, however, is better, and a supply in this fluid for smaller classes does not occupy much space.

II. It is well for the teacher or the assistant to prepare thin sections for the class. Very thin and uniform sections may be cut with a sharp razor in such a hand microtome as that designed by Professor Bastin (Bausch and Lomb Optical Co., Rochester, N.Y., No. 2550, fifteenth edition of their

Catalogue). Very thin sections may be placed in strong alcohol to bleach, and kept there indefinitely. They should, however, be placed in water for about an hour before being examined.

If compound microscopes are available, the study of the histology of the stems of the Sunflower, Cosmos, Corn, Walnut, etc., may be carried on more thoroughly, and several exercises devoted to it.

VI. The teacher should explain thoroughly the significance of the ordinary association of these three kinds of structures.

VII. Indian Corn stem may be preserved in the same way as the Sunflower or Cosmos stem.

VIII. Sections may be cut in the same way as in the case of the stem of the Sunflower.

X. To be contrasted with the statement in § VI.

XII. The Basswood or Linden and the Sycamore or Buttonball are excellent stems for this purpose. Sections may also be cut of these stems upon the hand microtome.

CHAPTER V

LEAVES. I

General Reading

Kerner and Oliver, Volume I, Part 2, pp. 593-597, 626-640.

Allen, The Story of the Plants, pp. 33-53.

Lubbock, Flowers, Fruits, and Leaves, pp. 97-147.

Gaye, The Great World's Farm, pp. 157-176.

Gray, Text-book, pp. 85-106; Elements, pp. 49-59.

I, 7. Read *Kerner and Oliver*, Volume I, Part 2, p. 595 (the italicized portion), for a definition of a leaf, and then the discussion leading up to it upon pp. 593 and 594.

I. Any simple leaf with an unlobed blade, a good petiole, and stipules will do. Apple leaves, Pear leaves, Quince leaves, etc., are good. The round-leaved Pelargoniums also have good leaves for this purpose. In all the work upon leaves in I–XII the specimens may be dried and even glued to paper. Fresh living specimens, however, are better.

III. The *Pittosporum eugenioides* (with yellowish foliage and black twigs) occasionally grown in greenhouses East, but a fairly common ornamental shrub in middle California, is most excellent for showing the netted venation. Species of Cherry, etc., are also very good.

V. Besides the Lily of the Valley, the leaves of *Scoliopus Bigelovii* of California, of the Bellworts (*Oakesia*, etc.), *Cypripediums* (native sp.), etc., are fairly good.

XII. The teacher may emphasize the descriptive terms as much as may be thought best under the circumstances. It is excellent drill to make the students apply terms with accuracy. At the same time, suggestions as to the reasons for the various shapes will be found in the reference to Lubbock's book given at the beginning of the notes upon this chapter, and for matters of the same kind concerning the different character of different leaf surfaces, read *Kerner and Oliver*, Volume I, Part 1, pp. 307–325.

XIII–XIV. Read *Kerner and Oliver*, Volume I, Part 1, pp. 279–283; and *Gray*, Text-book, pp. 85–90; Elements, pp. 142–144. It will be well for the student to make a careful study of the internal structure of the leaf, with the

aid of the compound microscope. The function of each of the different tissues should be emphasized.

XV. Read the reference in Grant Allen's *The Story of the Plants*, given above. The various kinds of work done by the leaves should be very decidedly emphasized by the teacher.

CHAPTER VI

LEAVES. II

General Reading

Gray, Text-book, pp. 106-110; *Elements*, pp. 60-62.

Lubbock, *Flowers, Fruits, and Leaves*, pp. 117-147.

I. Various species of *Aster*, *Solidago*, Flax, Butter-and-Eggs, etc., will do; in fact, any species with well-developed sessile leaves.

II. Plants with good perfoliate leaves are not at all common, and at present the writer can recommend only this species of the eastern portion of the United States, and the European *Bupleurum rotundifolium*.

III. *Eupatorium perfoliatum*, the common Thoroughwort or Boneset of the eastern half of the United States, is also excellent. Likewise the Fuller's Teazel common in many parts of the country.

IV. Acacias with phyllodia are commonly grown throughout middle and southern California and are very frequently met with in the greenhouses in the rest of the country. Seedlings are not uncommon in California.

Read *Gray*, Text-book, p. 110, § 217; *Elements*, p. 61, § 162; *Lubbock*, *Flowers, Fruits, and Leaves*, pp. 120, 121.

V. *Lathyrus Aphaca* is a European species and not accessible, as far as the writer knows, to students in this country.

The student may be shown pictures of this, and the relationship to the forms with imparipinnate and cirrhiferous pinnate leaves brought out.

Read *Gray*, Text-book, p. 109, § 216, and pp. 100, 101, § 195; *Lubbock*, Flowers, Fruits, and Leaves, pp. 137, 138.

VI. Read *Gray*, Text-book, p. 109, § 215; *Lubbock*, Flowers, Fruits, and Leaves, pp. 106, 107.

VII. Read *Gray*, Text-book, pp. 108, 109.

VIII. Read *Lubbock*, Flowers, Fruits, and Leaves, pp. 119, 121, and 122, Figs. 76 and 77; *Kerner and Oliver*, Volume I, Part 1, pp. 326 (under "Australian Proteaceæ"), 335 (bottom line), 336, and II, Part 1, p. 471.

The *Eucalyptus* species are abundant in California and are occasionally found in greenhouses in other parts of the country. Dried and pressed specimens may be used where fresh material is not available.

IX. The so-called "Smilax" of the greenhouses (*Myrsiphyllum asparagoides* or *Asparagus medeoloides*) is very generally accessible all over the country. In studying this plant, it is well to emphasize the fact that we consider a structure borne in the axil of a leaf as a branch structure, and a structure bearing another structure in its axil as a leaf structure. These points cannot be emphasized either too strongly or too often.

Read *Gray*, Text-book, pp. 65, 66, § 127; *Elements*, pp. 61, 62, § 164.

XI. Read *Kerner and Oliver*, Volume I, Part 1, p. 339 (under *Oxalis*).

Read also *Kerner and Oliver*, Volume I, Part 1, pp. 338 (bottom) and 339.

XII. Read *Kerner and Oliver*, Volume I, Part 2, pp. 532-539.

XIII. Read *Gray*, Text-book, p. 102.

XIV. Read *Lubbock*, Flowers, Fruits, and Leaves, p. 123.

Live Oaks are excellent for Californian students. Leaves of the so-called Laurel of the East (*Kalmia*), of Rhododendrons, Azaleas, Hollies, etc., are also excellent.

XV. Pressed specimens, illustrating the different methods of defoliation, may be mounted upon sheets of Bristol board.

Read *Kerner and Oliver*, Volume I, Part 1, pp. 355-361.

CHAPTER VII

PHYLLOTAXY

General Reading

Kerner and Oliver, Volume I, Part 1, pp. 396-400; Part 2, pp. 401-430.

Lubbock, Flowers, Fruits, and Leaves, pp. 97-118.

Gray, Text-book, pp. 119-131; Elements, pp. 67-71.

I. Almost any plant with opposite leaves will do just as well as Fuchsia. It is recommended because it is usually very readily obtainable. Erect branches are desirable.

III. Any plant with whorled leaves may be used. Certain Lilies (*Lilium* sp.) are good. The *Galium* species, however, occur almost everywhere.

IV. Elms, Basswoods or Lindens, Indian Corn, and various Grasses are good. But *Iris*, *Hemerocallis* (Day Lily), etc., while showing the two ranks excellently, do not allow the insertion of the leaves to be determined with sufficient readiness.

VII. Three-ranked arrangements are by no means common. Those who live in the eastern portions of the United States may obtain the *Veratrum* in the spring, and no more excellent object can be found. The *upright shoots* of Alders, Hazels, and Beeches sometimes show it very distinctly, and teachers who have not access to *Veratrum* should seek suitable materials from these plants.

VIII. The upright wand-like shoots, lighted equally or nearly so from all sides, of young plants or of branches from the roots or bases of the plants mentioned should be used. Sumachs, Willows, and Oaks are excellent. Where Willows have been pollarded, the adventitious vertical branches which spring out make excellent objects, especially in the case of the broader leaved *S. discolor*, *S. cordata*, and *S. lucida*.

IX. Read *Kerner and Oliver*, Volume I, Part 1, p. 400, for further cases.

XI. Cones of Larch, *Sequoia gigantea*, Sugar Pine, etc., are excellent. Read carefully the references to this subject in *Kerner and Oliver* and in *Gray*, recommended above. The numbering of the scales of cones is an excellent task for students to perform outside of the laboratory.

XIII, XIV. Read *Kerner and Oliver*, Volume I, Part 2, pp. 414-417 and 419, 420, especially compare Figs. 106 and 109; *Lubbock*, Flowers, Fruits, and Leaves, pp. 108-111.

XV. Read *Kerner and Oliver*, Volume I, Part 2, pp. 405 (bottom line)–407.

XVI. Another view is frequently expressed ; for which read *Kerner and Oliver*, Volume I, Part 2, p. 402.

Read *Gray*, Text-book, p. 127.

The latest writers disagree with Sachs, however, and consider these spirals as secondary and the number of ranks as greater than three.

CHAPTER VIII

BUDS

General Reading

Kerner and Oliver, Volume II, Part 1, pp. 25–45.

Gray, Text-book, pp. 40–45 ; Elements, pp. 27–32.

MATERIAL, consisting of branches with buds, may be tied up into bundles and dried. If placed in boiling water and allowed to remain there until the water is cool, all the parts will swell up to their normal size again and will serve the same purposes as fresh material.

V. The large-leaved Maple of California and the Red or the Silver Maple of the East are excellent.

VI. Material should be fresh or preserved in formalin.

Read *Gray*, Elements, p. 63, § 166 (Buckeye) ; Text-book, p. 116, § 227 (Buckeye).

The scales of large specimens of the Buckeye or of the Red Currant may be carefully picked off, pressed, and the series of transitions from scales to leaves pasted upon cards and given to the students in that form.

The teacher should explain *homology* and *analogy* at this point and emphasize all cases hereafter.

VII. The *Pittosporum* is the *P. eugenoides*, common in cultivation in California, with yellowish green foliage and black-stemmed twigs. The winter bud is pronounced and the homology between the bud-scale and the blade of the leaf is readily demonstrated. Series of scales pressed and mounted upon cards may be made in either of these cases or the class may work from fresh or formalin material.

VIII. The same recommendations apply also to this paragraph.

Read *Kerner and Oliver*, Volume I, Part 1, pp. 351-353, Fig. 91 (Tulip Tree) and Fig. 92 (Beech).

IX. Compare *Kerner and Oliver*, Volume I, Part 1, Fig. 90, 3 and 4 (p. 349) (Walnut).

XII. Read *Kerner and Oliver*, Volume II, Part 1, pp. 25-28, 29, 30, 37-45.

CHAPTER IX

PRÆFOLIATION

General Reading

Kerner and Oliver, Volume I, Part 1, pp. 347-355.

Gray, Text-book, pp. 132, 133 (also 134-140 for flower buds especially).

FORMALIN or fresh material is necessary for the study of præfoliation. The buds should be taken as they are just opening if winter buds, but the vegetative buds also furnish good demonstrations. If opening winter buds are not available, large quiescent buds will do, but they are not so easily manipulated.

CHAPTER X

PROTECTION

General Reading

Kerner and Oliver, Volume I, Part 2, pp. 430-451.

Hardinge, With the Wild Flowers, pp. 217-258 (Poisonous Species).

Gray, Text-book, pp. 55 (§§ 112, 113), 117 (§ 227 a); Elements, pp. 41 (§§ 101, 102), 64 (§ 167).

Croupin, The Thorns of Plants (Popular Science Monthly, Volume 46, pp. 498-501 (with figures), 1895).

I. The Orange, Lemon, or any of the *Cratægus* sp., *i.e.* Scarlet Thorn, Hawthorn, or Cockspur Thorn, are excellent. Leafless branches may be dried and soaked out again as recommended under Chapter VIII.

II. In the Eastern Barberry (*Berberis vulgaris*), after the leaves have appeared in the spring, a complete series of gradations from leaves to spines may be traced in many instances. Read *Gray*, Elements or Text-book, referred to above.

III. The long, slender, upright shoots from the base of *Robinia Pseudacacia* show these spines beautifully. The *Acacia armata* or Spiny Acacia is fairly commonly grown in California and to some extent in the greenhouses East. The stems of the *Euphorbia splendens*, common in greenhouses all over the country, is also armed with spines occupying the places of stipules. The spines in *Xanthium spinosum*, a frequent weed in California, are also stipular.

IV. The prickles of Roses and of Brambles are in many cases especially adapted more for climbing than for protection. Read *Kerner and Oliver*, Volume I, Part 2, pp. 671 (bottom line)–673.

VIII. Read *Kerner and Oliver*, Volume I, Part 2, pp. 441–443.

XI. Read *Kerner and Oliver*, Volume I, Part 1, pp. 307–346, 347–355 ; and Volume I, Part 2, pp. 548–552.

CHAPTER XI

STORAGE

General Reading

Kerner and Oliver, Volume I, Part 2, p. 749 (bottom), 750, 751 (bottom), 752, 624.

Gray, Text-book, pp. 31, 32, 57–64, 115, 116, and 14–26; Elements, pp. 35, 36, 43–48, 62, 63, and 17–26.

Allen, The Story of the Plants, pp. 68–72.

THE materials for illustrating storage are generally accessible. Small specimens of Cacti, Agaves, Aloes, etc., may be obtained from the florist in pots. Corms, bulbs, etc., can be obtained from the florist at certain seasons, when it is well to preserve a supply in formalin. Radishes, Carrots, Beets, Potatoes, etc., can be obtained in the market at almost any time.

Besides the rough morphological study outlined, the student may with advantage study thin sections of the thickened parts and test for the particular reserve materials as recommended in the case of seeds (see p. 144).

II. Species of Live-for-ever are also good.

III. The root-stocks of the Solomon's Seal are also excellent for this purpose.

IV. The Jerusalem Artichoke has excellent tubers. The teacher should provide, if possible, a young plant of the Potato or Artichoke, with as much of the underground portion as possible, showing at least the slender underground branches with the tubers at the ends.

V. The Corms of the Crocus and of the Indian Turnip or Jack-in-the-Pulpit are excellent. Gladiolus is usually readily obtainable from the florist at the proper season for planting. Various Brodiaeas are common throughout California.

VII. Scaly bulbs are not always readily obtainable. One of the best is that of *Lilium auratum*, obtainable in the spring from the florist, but they are somewhat expensive. The Bermuda or Easter Lily is cheaper and may be obtained usually during the winter. The native Lilies are good. Californians may generally obtain excellent *Lilium* bulbs in Chinatown, at any rate in the larger cities. The Chinese use them for food.

IX. The Ornithogalum, or Star-of-Bethlehem, has also very good tunicated bulbs.

CHAPTER XII

CLIMBING PLANTS

General Reading

Kerner and Oliver, Volume I, Part 2, pp. 669-710.

Gray, Text-book, pp. 34, 35, 51-53, 54, 55, 117-118.

Allen, The Story of the Plants, pp. 178 (bottom)-180.

Darwin, Climbing Plants.

THE hints contained in the introductory paragraph should be emphasized by the teacher and illustrations suggested or called forth from the class. The struggle for light and air thus illustrated will not be easily impressed upon their minds in any other way. It is important that these points should be made plain in order that the student may understand why it is that plants take to climbing.

I. *Manettia* is a common plant with the florist. Small ones, trained about slender stakes, may often be obtained in pots, and in this condition are readily available for observation in the laboratory.

II. Any species of *Ipomœa* will do. Several species are grown in the greenhouses. *I. purpurea*, the common Morning Glory, may be readily raised from seed in pots and allowed to twine about slender stakes.

IV. Especially Beans, Cypress Vines, Dutchman's Pipes, Yams, etc.

V. The Grapevine also has excellent tendrils, but their homology with branches is not easily made out. *Ampelopsis* sp., *i.e.* the Virginia Creeper and the Japanese Creeper, have tendrils which form suckers at the ends and attach themselves to flat surfaces in this way.

VI. Peas can be raised very easily in boxes in the laboratory. Five to six weeks will generally be sufficient for their growth.

VIII. *Solanum jasminoides* may often be obtained from florists, during the winter, in small pots and will climb about slender supports.

Compare *Gray*, Text-book, p. 117, Fig. 235.

IX. Pressed specimens often show the habit very well.

CHAPTER XIII

EPIPHYTES, PARASITES, AND SAPROPHYTES

General Reading

EPIPHYTES :

Kerner and Oliver, Volume I, Part 1, pp. 115 (bottom)–117;
Part 2, pp. 753, 754.

PARASITES :

Kerner and Oliver, Volume I, Part 1, pp. 171–215.

SAPROPHYTES :

Kerner and Oliver, Volume I, Part 1, pp. 99–119.

As the laboratory work proceeds, the relationships existing between epiphytes, parasites, and saprophytes should be brought out and the gradations between the various kinds.

I. These Aërial Orchids, as they are called, are generally obtainable, and may perhaps be borrowed or hired of the florist.

II. The Rock Lichens are also good examples. The “symbiosis” character of the Lichen may be explained by the teacher if desirable.

Read *Kerner and Oliver*, Volume I, Part 1, pp. 243–248.

III. Mistletoes are fairly readily obtainable in California and in the southern portion of the United States from the Rocky Mountains eastward, from oaks, etc. Pieces of the branches upon which they grow should be taken with them. In other parts of the country, supplies must be drawn from correspondents or from the florists who have supplies about Christmas time, but such specimens usually lack any portion of the host plant.

IV. Compare *Kerner and Oliver*, Volume I, Part 1, p. 209, Fig. 48.

VI. Species of Dodder (*Cuscuta*) are common all over the country. Material is best when fresh or preserved in formalin, but may also be dried and soaked out again.

VIII. The Bread-Mould is a very good example of a saprophyte and also of a group of plants of which we have, as yet, had no example in our work; viz. of *flowerless- or spore-plants*. The Coral Roots (species of *Coralorhiza*) are fairly widely distributed and may be studied. The Indian Pipe (*Monotropa*) is perhaps more properly a parasite upon a mould. The insectivorous plants treated under the next chapter are also saprophytes, but as they obtain their organic materials in an entirely different way, they are not included here. The teacher, however, should call the attention of the students to this fact.

IX. Read *Kerner and Oliver*, Volume I, Part 1, pp. 213-215.

CHAPTER XIV

INSECTIVOROUS PLANTS

General Reading

Kerner and Oliver, Volume I, Part 1, pp. 119-158.

Allen, The Story of the Plants, pp. 63-68.

Gaye, The Great World's Farm, pp. 149-151.

Gray, Text-book, pp. 110-115; Elements, pp. 64-66.

Darwin, Insectivorous Plants.

I. In the eastern United States, both to the north and to the south, some species of Pitcher Plant (*Sarracenia*)

may be obtained. Other districts must needs be supplied by friends or by some botanical supply company. (The Cambridge Botanical Supply Co., Cambridge, Mass., advertises that it will obtain botanical materials for teachers.) Plants may be kept growing in the laboratory if the pots are kept immersed in several inches of water. Dried leaves may be kept from season to season, being soaked up in water when needed. Species of *Nepenthes* are often grown in conservatories.

II. The *Darlingtonia* is difficult to obtain except occasionally from florists who deal in native plants.¹ It is easily grown in the same way as *Sarracenia*s are.

IV. The Venus Flytrap is very restricted in its range, but is fairly readily grown in sand in a pot immersed in a few inches of water. It may be obtained through dealers in native plants.¹

VII. The teachers in the eastern United States can obtain *Drosera* species. Others may sometimes obtain them from florists. They should be grown in peat and *Sphagnum*, but do not flourish as well as the plants previously mentioned.

The Bladderworts (*Utricularia* sp.) may also be used if accessible to the teacher, as they are in much of the country east of the Rocky Mountains.

If laboratory material is unobtainable, the teacher will lecture upon this chapter and show specimens or illustrations.

¹ Such as Edward Gillett, Southwick, Mass., or F. H. Hosford & Co., Charlotte, Vt.

CHAPTER XV

REPRODUCTION

IN beginning to consider the matter of reproduction, it must be borne in mind that it is to this end that the plant works. It strives first to build up a strong healthy body or vegetative portion, and to accumulate proper materials, both in kind and in quality, in order that the provisions made for *reproducing its kind* and *perpetuating the species* may be adequate.

It is for the purpose of providing for this that some plants find it advantageous to protect themselves against unfavorable conditions and animals which would otherwise prey upon them, to store up nourishment to be expended for this purpose, to adopt the habits of epiphytes, parasites, saprophytes, or insectivorous plants, to grow high, to remain low, or to climb up over their neighbors. In fact, every variation in plant structure and habit is probably explainable upon the idea that the plant has to struggle to maintain itself in a condition to reproduce its kind. That some plants adopt one set of methods, and others, another, leads to the infinite variation in plant life which we find.

CHAPTER XVI

VEGETATIVE REPRODUCTION

General Reading

Kerner and Oliver, Volume II, Part I, pp. 25-45 and 452-463.

Gray, Text-book, pp. 43 (§§ 73, 74), 45 (§ 77), 53 (§§ 105-108), 56-60 (§§ 115-117), 63 (§§ 123, 124).

I. *Lilium tigrinum*, or Tiger Lily, is in common cultivation in the East, and may be obtained through florists there or elsewhere. *Cicuta bulbifera*, of the East, has also very excellent axillary bulblets. Some species of *Calochortus*, or Mariposa Lily, have subterranean axillary bulblets.

III. In the eastern United States many Wild Onions produce bulblets instead of flowers.

IV. Cultivated species of *Dioscorea*, obtainable from florists.

CHAPTER XVII

SEED REPRODUCTION

THE general reading is so extensive and the number of subjects so great that the references will be given under the heads of the several succeeding chapters. It has seemed simplest and best in this little guide to distinguish seed and spore reproduction, since we shall have no means of examining the finer details of the embryology of the forms either

higher or lower. They are related to one another something as oviparous and viviparous reproductive methods in the animals, *i.e.* they are not different in kind, but in spore reproduction the reproductive body (the spore) is separated from the parent while still in a very simple and very primitive condition; while in seed reproduction, it is retained longer in connection with the parent until it has developed within it a rudimentary plantlet, with provision for rapid development of root, stem, and leaf. A number of plants possess a kind of reproduction intermediate between the two.

CHAPTER XVIII

A TYPICAL OR PATTERN FLOWER

General Reading

Gray, Text-book, pp. 176-179 (§§ 323-325); *Elements*, pp. 81, 82 (§§ 239, 240).

I. *Crassula* species are to be obtained from the greenhouse, and it will be best to preserve a quantity in formalin solution. If *Crassula* is not available, some species of *Sedum* may be obtained. *Sedum* has two circles of stamens, and the alternation of the circles seems to be disturbed. With a little foresight the teacher can usually obtain the flowers of some species either of *Sedum* or *Crassula*, either fresh or preserved in fluid.

VIII. The teacher will do well to study the floral diagrams or ground plans given in *Gray* and also in *Kerner* and *Oliver* under various paragraphs.

Compare *Gray*, Text-book, p. 176, Fig. 327; *Elements*, p. 82, Figs. 225 and 227.

CHAPTER XIX

FERTILIZATION

General Reading

Kerner and Oliver, Volume II, Part 1, pp. 401-420.

Gray, Text-book, pp. 215-218 and 283-285.

Allen, The Story of the Plants, pp. 73-86.

Gaye, The Great World's Farm, pp. 190-207.

THE distinction between *pollination* and *the descent of the pollen tube* upon the one hand and *fertilization* upon the other is one demanding much emphasis, and the teacher must not only impress it upon the pupil, but must constantly guard against the misuse of the terms both upon his own part and upon that of the pupil as well.

Fertilization refers to the whole process upon which the development of the embryo depends. This technical use must be guarded from confusion with the fertilization of the soil either natural or artificial. The process of *pollination* is the process which may be studied with the facilities open to the ordinary student, and must be studied in the field to be comprehended in its variety of interests. Some typical examples may be brought into the laboratory, but excursions with the view of examining the plants in their natural habitat, and encouragement to the pupils to make excursions for themselves, to watch and attempt to make out the details of the fertilization in as many different kinds of flowers as possible, is very necessary. Such work as this is far better than any laboratory work which can be conceived of.

CHAPTER XX

IMPERFECT, INCOMPLETE, AND UNSYMMETRICAL FLOWERS

IMPERFECT FLOWERS:

Read *Kerner and Oliver*, Volume II, Part 1, pp. 291-299.

Gray, Text-book, pp. 193 (§ 353) and 218 (§ 405).

Allen, The Story of the Plants, pp. 105 (bottom line)-109.

Gaye, The Great World's Farm, pp. 208-212.

I. 6. In this case it is intended to call attention to the more complete crossing in dioecious plants than must necessarily take place in monœcious plants. Read, also, *Kerner and Oliver*, Vol. II, Part 1, pp. 300 (section at bottom of the page), 301; and *Gray*, Text-book, pp. 215 (note under Kerner's "Flowers and their Unbidden Guests"), 216, for the terms *Autogamy*, *Allogamy*, *Geitonogamy*, and *Xenogamy*.

II. The *perianth*, i.e. the floral envelopes (calyx and corolla), serves two separate kinds of functions. First, it protects the maturing essential organs until they are in a condition to perform their functions. Second, it serves, in insect-pollinated flowers, to attract insects both by its color, and by the nectar which it secretes. It is by no means easy to determine in most cases why one or both circles of the perianth are absent.

Read *Gray*, Text-book, pp. 187-195.

III, IV. *Irregularity* is generally explainable after more or less careful study upon the basis of adaptation to insect-pollination. The papilionaceous flower in its various forms, and the flowers of the Larkspur, Monkshood, Pansy, etc., are excellent examples and worthy of detailed study.

Read *Kerner and Oliver*, Volume II, Part 1, pp. 228, 260, 261, 267, 268; *Gray*, Text-book, pp. 184-189, 225-229; *Allen*, The Story of the Plants, pp. 90-98; *Lubbock*, Flowers, Fruits, and Leaves, pp. 27-30.

V. Orchids of various kinds may generally be obtained from the greenhouses. The pollen masses may be demonstrated and the method of their withdrawal. Certain native species, especially of *Habenaria*, may often be obtained. The material used should be alive and a pencil tip or a bristle be employed to represent the proboscis of an insect.

Read *Kerner and Oliver*, Volume II, Part 1, pp. 254-257, 269, 270; *Gray*, Text-book, pp. 230-234; *Weed*, Ten New England Blossoms, pp. 72-89; also *Darwin*, On the Fertilization of Orchids by Insects.

Species of Milkweed (*Asclepias*) have pollinia, and living material may be introduced into the laboratory whenever possible and the process of pollination be demonstrated.

Read *Kerner and Oliver*, Volume II, Part 1, pp. 257-260; *Gray*, Text-book, p. 233 (bottom).

VI. The lack of symmetry is usually connected more or less directly with irregularity and is brought about by the suppression of parts of different circles.

Read *Gray*, Text-book, pp. 187-190.

CHAPTER XXI

COALESCENCE AND ADNATION

COALESCENCE and adnation are directly concerned in the same way as irregularity, in devices to ensure insect pollination. They modify the structure of the flower so as to exclude insects of no use for this purpose, and to cause the

proper insects to enter the flower in such a fashion as to benefit it in the most satisfactory way. Hints of this may be obtained by reading from this point of view *Kerner and Oliver*, Volume II, Part 1, pp. 221-243 and 243-276.

I. Read *Kerner and Oliver*, Volume II, Part 1, p. 249.

III. Read *Gray*, Text-book, pp. 259-268; *Kerner and Oliver*, Volume II, Part 1, pp. 72-84.

V. Read *Kerner and Oliver*, Volume II, Part 1, p. 247, Fig. 266.

CHAPTER XXII

WIND- AND INSECT-POLLINATION.

I. *Kerner and Oliver*, Volume II, Part 1, pp. 129-151.

Gray, Text-book, pp. 217, 218.

Lubbock, Flowers, Fruits, and Leaves, p. 7 (top).

Allen, The Story of the Plants, pp. 124-135.

Gaye, The Great World's Farm, pp. 208-214.

Hardinge, With the Wild Flowers, pp. 47-55.

Weed, Ten New England Blossoms, pp. 1-17.

The Indian Corn is certainly a most excellent example of a wind-pollinated plant, and may usually be obtained or, at least, explained, as its general arrangement is known to all. The feathery stigmas of other Grasses are also extremely instructive, taken into connection with the versatile anthers.

II. *Kerner and Oliver*, Volume II, Part 1, pp. 152-167.

Gray, Text-book, pp. 218, 219.

1. *Kerner and Oliver*, Volume II, Part 1, pp. 182-198.

Lubbock, Flowers, Fruits, and Leaves, pp. 13, 14.

Allen, The Story of the Plants, pp. 86-96, 103, 104.

Allen, The Colors of the Flowers.

2. *Kerner and Oliver*, Volume II, Part I, pp. 198-209. *Lubbock*, Flowers, Fruits, and Leaves, p. 43.
3. *Kerner and Oliver*, Volume II, Part I, pp. 167-182. *Lubbock*, Flowers, Fruits, and Leaves, pp. 32-42.
4. (a) *Kerner and Oliver*, Volume II, Part I, pp. 280 (bottom line), 281, Fig. 280.
4. (b) *Kerner and Oliver*, Volume II, Part I, pp. 263 (bottom paragraph), 264.
4. (c) *Gray*, Text-book, p. 229 (§ 419, Figs. 455-457).

The Special Devices, however, are not limited to these examples which are introduced here especially to show automatic movements of the essential organs. The teacher after carefully studying the various devices described in the first part of *Kerner and Oliver's* Natural History of Plants, and *Gray's* Text-book, will doubtless be able to provide a number of interesting forms and to demonstrate the working of the particular mechanism or structure. Attention may be called, however, to two cases, viz. : —

Salvia. *Kerner and Oliver*, Volume II, Part I, pp. 262, 263. *Lubbock*, Flowers, Fruits, and Leaves, pp. 20-22 ; and *Compositæ*. *Gray*, Text-book, pp. 223, 224. *Lubbock*, Flowers, Fruits, and Leaves, pp. 25, 26 ;

as being easily obtainable and demonstrable. *Compositæ* are readily obtainable everywhere, the common Sunflower and Cosmos are good, and species of *Salvia* are commonly cultivated.

5. *Dichogamy*. Read *Kerner and Oliver*, Volume II, Part I, pp. 306-317 ; *Gray*, Text-book, pp. 219-225 ; *Allen*, The Story of the Plants, pp. 101, 102 ; *Lubbock*, Flowers, Fruits, and Leaves, pp. 16-19.
6. *Scrophularia nodosa* and *S. Californica* are equally suitable and allow the use of this plant in almost any

portion of the United States. Plantains are common. The species with the longer spikes are preferable. Specimens in formalin solution may be used when fresh material is not available.

7. Some *Pelargoniums*, also, are excellent, but others are not. For *Geranium*, compare *Lubbock*, Flowers, Fruits, and Leaves, p. 8, Figs. 5 and 6. The various *Mal-*
lows are excellent, for the stigmas of most species remain within the stamen tube until the anthers have shed their pollen, then emerge and expand. The larger flowered *Willow-herbs* (*Epilobium* species) are excellent also, as may be seen from *Gray*, Text-book, p. 222, and *Kerner and Oliver*, Volume II, Part 1, p. 309, Fig. 293. Preserved material will answer very well, but the teacher will find that a very large number of different species of flowers are protandrous and a considerable number protogynous.
8. *Heterostyly*. Read *Kerner and Oliver*, Volume II, Part 1, pp. 302, 303, 396-399, and 405; *Gray*, Text-book, pp. 234-239 (under *Heterogonous Dimorphism and Trimorphism*); *Lubbock*, Flowers, Fruits, and Leaves, pp. 30-33; *Weed*, Ten New England Blossoms, pp. 18-32 (*Mayflower*, *Epigæa repens*).

The *Bluets* are well adapted for the demonstration of heterostyly, but are available for the most only east of the Mississippi River. Other species of *Houstonia* extend somewhat west of that. The blossoms of the *Partridge Berry* (*Mitchella repens*) and of the *Mayflower* (*Epigæa repens*) are also excellent, but the range of these plants is limited and Eastern.

The *Primroses* of the gardens and greenhouses do very well, but very frequently one can find only one "length of

style." Teachers will do well to obtain supplies of preserved material either by their own efforts or those of their friends, or purchase them from the "Botanical Supply Co." at Cambridge, Mass.

9. The Purple Loosestrife is occasionally planted and seeds may be obtained through the larger florists. Other species of *Lythrum* may do fairly well, such as the western and Pacific coast species. *Nesaea* occurs in the United States east of the Mississippi River.
10. Read the reference in *Kerner and Oliver* given above. Some *Eschscholtzias* have four long styles, and some two long ones, but the majority have two long ones and two short. The *Eschscholtzia* is easily obtained in California and is frequently cultivated elsewhere in the United States.

Protection of Pollen.—The teacher may read and call the attention of the students to the various devices (such as opening and closing, possession of glutinous coverings etc.) for protecting the pollen from unfavorable weather and from undesirable insects. Many cases illustrative of these points will suggest themselves from the following references:—

Kerner and Oliver, Volume II, Part I, pp. 104-129, and 230-243; *Lubbock*, Flowers, Fruits, and Leaves, pp. 37-42.

CHAPTER XXIII

SELF-POLLINATION

General Reading

Kerner and Oliver, Volume II, Part I, pp. 331-401.

THESE pages give a review of the general subject of self-pollination or *Autogamy* which results in close-fertilization, a phenomenon of much more frequency than has been generally supposed.

Gray, Text-book, pp. 240-242.

I. *Weed*, Ten New England Blossoms, pp. 90-98 ; *Kerner and Oliver*, Volume II, Part I, p. 393.

Species of *Polygala* with cleistogamous flowers occur over nearly the whole of the United States. Pressed specimens may be used as well as fresh ones. *P. polygama* is one of the best species, since the cleistogamous flowers are numerous and may be obtained in all stages.

In regard to the cleistogamous flowers of Violets, read *Lubbock*, Flowers, Fruits, and Leaves, pp. 53-57.

CHAPTER XXIV

ANTHOTAXY

General Reading

Kerner and Oliver, Volume I, Part 2, pp. 736-749.

Gray, Text-book, pp. 141-162.

Allen, The Story of the Plants, pp. 135-149.

THE general work upon the flower clusters is morphological and comparative. It shows how practically the same result is obtained by the different plants in very different ways. Besides those flower clusters mentioned in the guide the following may be studied : —

HELIOTROPE. *Gray*, Text-book, pp. 153 (§ 281)—155.

DOGWOOD. Species of *Cornus*, such as *C. Canadensis*, *C. florida*, and *C. Nuttalliana*. *Gray*, Text-book, pp. 152, 153; *Kerner and Oliver*, Volume II, Part 1, pp. 183, 184, 231, Fig. 260.

CHAPTER XXV

METAMORPHOSIS

General Reading

Kerner and Oliver, Volume I, Part 2, pp. 594-597.

Gray, Text-book, pp. 5-8, 167-174.

AT the close of this chapter, it will be well for the teacher, assuming that three primary organs, root, stem, and leaf, are modified in one way and another to do all the work of the plant, to review all the previous chapters from this point of

view, showing how one plant modifies one of these three organs to do a certain kind of work, and another plant another one of the three to do the same kind of work, and so on.

CHAPTER XXVI

FRUITS

General Reading

Kerner and Oliver, Volume II, Part 1, pp. 426 (bottom)-436.
Gray, Text-book, pp. 285-287.

THE teacher will need to emphasize the distinction between the popular and the scientific uses of the term *fruit*. Fruit is used as a household term in a loose way to designate those fruits which are ordinarily eaten raw, while such fruits as Tomatoes, Egg-plants, etc., which are cooked, are classed with Cabbages, Potatoes, etc., under the general head of "vegetables."

CHAPTER XXVII

FLESHY FRUITS

General Reading

Kerner and Oliver, Volume II, Part 1, pp. 427, 428; Part 2, pp. 862-866.
Gray, Text-book, pp. 297-303.
Lubbock, Flowers, Fruits, and Leaves, pp. 73-75.
Gaye, The Great World's Farm, pp. 270-276.
Allen, The Story of the Plants, pp. 154-158.

FLESHY fruits may usually be obtained in the market. Some kinds are sold dried and may be soaked out before

being given to the class. Formalin solution also preserves them well.

I. Preserved Cherries are useful when no fresh ones are obtainable, and Prunes may be soaked over night.

I. 5. *Kerner and Oliver*, Volume II, Part 2, p. 865 (top).

IV. Cranberries remain in the market for a considerable time, but it is well to preserve a quantity in formalin solution.

XIV. The Rose-hip and the Fig may be studied if time and material allow, to show fruits in which the receptacle enclosing the real fruits becomes fleshy, while the Strawberry is a good example of dry fruits (achenes) borne upon the outside of a very fleshy and succulent receptacle.

CHAPTER XXVIII

DRY DEHISCENT FRUITS

General Reading

Kerner and Oliver, Volume II, Part 1, pp. 429-432; Part 2, pp. 833-840.

Lubbock, Flowers, Fruits, and Leaves, pp. 53-65.

I-III. The references given above apply especially to fruits which are noticeably explosive. Perhaps all dehiscent fruits are more or less explosive, but the evidence is not so plain in the majority of cases. In the paragraphs that follow, more attention is paid to the method of dehiscence.

III-VIII. *Gray*, Text-book, pp. 288-293; *Lubbock*, Flowers, Fruits, and Leaves, p. 65, Fig. 46.

Materials for explosive fruits may be dried and the explosive character may be inferred after explosion. Occasionally the phenomenon may be observed in the laboratory, or the student may keep the fruits under observation at home until it occurs. For methods of dehiscence, the plants recommended are generally accessible at the right season (*i.e.* after flowering) and the dried, opened capsules may be stored in pasteboard boxes until needed. Care must be taken to obtain a suitable Poppy. The smaller red or white garden species are usually excellent.

CHAPTER XXIX

DRY INDEHISCENT FRUITS

General Reading

Gray, Text-book, p. 294 (§ 562).

Kerner and Oliver, Volume II, Part 1, p. 429.

IN addition to the reading recommended in the following chapters, it will be well for the teacher to read what is said in *Kerner and Oliver's* "Natural History of Plants" upon *Creeping Mechanisms* (Volume II, Part 2, pp. 843, 844).

CHAPTER XXX

SEED DISPERSAL BY ANIMALS

General Reading

Kerner and Oliver, Volume II, Part 2, pp. 866-876.

Lubbock, Flowers, Fruits, and Leaves, pp. 75-80.

V. *Kerner and Oliver*, Volume II, Part 1, pp. 442-450.

VI. *Kerner and Oliver*, Volume II, Part 2, pp. 866, 867.

THE carrying of seed, even from one continent to another, by water-birds in the mud adhering to the feet or feathers should be brought to the notice of the class by the teacher, and the pupils induced to be upon the lookout for any cases which they can find, of dispersal by animals.

CHAPTER XXXI

SEED DISPERSAL BY THE WIND

General Reading

Kerner and Oliver, Volume II, Part 2, pp. 848-862.

Lubbock, Flowers, Fruits, and Leaves, pp. 79-82.

Hardinge, With the Wild Flowers, pp. 202-204.

Allen, The Story of the Plants, pp. 149-154.

Gaye, The Great World's Farm, pp. 253-256.

Gray, Text-book, pp. 294, 295.

MATERIALS of the fruits necessary for the work under this chapter may be procured at various times during the season and preserved dry in paper bags or boxes. The different powers and styles of sailing through the air should be tested in the laboratory.

CHAPTER XXXII

SEED DISPERSAL BY WATER

General Reading

Kerner and Oliver, Volume II, Part 2, pp. 845-848.

WATER dispersal is neither so common nor so frequently observed as that by wind or animals. Yet the students will find in the autumn that the quieter portions of brooks, and

especially of ponds, contain larger or smaller quantities of small floating fruits, mostly of the dry and indehiscent class.

I. Cocoanuts with the husks on, may often be obtained through the wholesale dealers in fruits.

CHAPTER XXXIII

SPORE REPRODUCTION

General Reading

Kerner and Oliver, Volume II, Part 1, pp. 8-25 and 49-70.

THE subject of spore reproduction, even in the narrower and limited sense in which the writer has used it, is so complex that it should really be considered in a course of study devoted especially to it, and requiring the use of the compound microscope and more complicated methods of manipulation than the writer considers best for beginners in botanical observation. At this point, however, the students may, with profit, if time and the facilities allow, take up a short course devoted entirely to the cryptogams.

Spores are of two kinds, as may be seen from the references above. They may be the result of a sexual process, *i.e.* of fertilization; or they may arise without any sexual process whatever. The spores recommended in the guide are all of the latter kind. They are introduced here simply to illustrate this kind of reproductive body, and the examples recommended are chosen first because they are fairly readily obtainable, and second, because they represent several of the more conspicuous and important groups of spore-plants. If compound microscopes are available, the spores and sporangia, at least, may be examined more care-

fully, and a few other forms such as *Spirogyra*, *Vaucheria*, *Peronospora* or *Cystopus*, *Puccinia*, *Uredo*, and *Aecidium* added.

FARTHER STUDY

When the student shall have finished a careful study of the morphology of the more conspicuous plants, and has seen some of the more important modifications of the different organs to perform different services to the plant, it will be well for him to study as many species as are readily accessible in suitable condition, with especial attention to the consideration of the life-history. It will be well to use some suitable manual of the botany of the region from which the name and the relationships of the species may be obtained. But the teacher should prevent this searching out of the name and the practice in the use of the analytical key from absorbing the principal portion of the attention. The practice in using the key is excellent logical discipline of a certain kind, but the training of the powers of observing correctly, and of making the proper inferences, should not be subordinated to it. The name should not be the end for which the work is done. The name serves two purposes: first, it furnishes a convenient designation to be used when studying, talking, or writing of the plant; and second, it enables the student to find out what others have written or think about the subject.

The principal attention of the student should be directed towards the morphology of the plant in as many of its different stages of development as possible. This study of the life-histories of the different species forms as profitable work as can be recommended for the student. Teachers may obtain suggestions in this direction from the chapter upon

Some Plant Biographies of Grant Allen's little book, "The Story of the Plants."

It is well, also, at this time, to introduce the student to some idea of species, genera, orders, etc., from the point of view of descent or phylogeny.

Read *Gray*, Text-book, pp. 315-331 (especially §§ 657-662) ; *Kerner and Oliver*, Volume II, Part 1, pp. 486, 487, and 495, 496 ; Part 2, pp. 497-600.

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Dehiscent

Collected

Product of simple
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Flora. Tree-wooden stem - the two
general areas (a) wood (b) bark
that portion that can be scraped
off the wood. These portions of
the bundles disengaged as bark bark
& soft bark - occur in the bark
These two barks forming the inner
bark. As the stem grows new
wood circles are laid down to
the original wood for xylem &
the bark-side of the inner
In the middle 1st & 2nd and
Section. Homologous the areas
differentiation by stem bark.
The same areas in Section
much to keep. Studied 1st roots
bark bark. bark. The bark
have become through compressed
through growth & growth
& growth wedge up bark
bark. bark. bark. bark. bark.
The bark.

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